Lockheed

Missiles & Space Company, Inc.

HUNTSVILLE RESEARCH & ENGINEERING CENTER

Cummings Research Park
4800 Bradford Drive,
Huntsville, Alabama

Remote Measurement Utilizing NASA's Scanning Laser Doppler Systems

Volume 1 — Final Report

Laser Doppler Wake Vortex Tracking at Kennedy Airport

March 1976

Contract NAS8-30971

Prepared for National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

by

M.C. Krause
D.J. Wilson
R.E. Howle
B.B. Edwards
C.E. Craven
J.L. Jetton

APPROVED: T R Lawrence

T.R. Lawrence, Supervisor
Laser Systems Section

J.S. Farrior

J.S. Farrior
President Director

FOREWORD

This document was prepared by personnel in the Laser Systems Section of Lockheed's Huntsville Research & Engineering Center for NASA-Marshall Space Flight Center. The work described was accomplished under Contract NAS8-30971 and is presented as Volume I of two volumes. Volume II is entitled "Laser Doppler Dust Devil Velocity Profile Measurement Program." The NASA-MSFC technical monitor and alternate monitor for this contract were James W. Bilbro, EB34, and Harold B. Jeffreys, EB34, respectively.

ACKNOWLEDGMENT

The authors are grateful to NASA-MSFC personnel for their assistance in preparation and moving the system to New York and Arizona test sites and to R.M. Huffaker and Dr. S. Idso for their assistance in conducting the dust devil velocity profile measurement tests.

CONTENTS

Section 1
INTRODUCTION AND SUMMARY

Test operations of the Scanning Laser Doppler System (SLDS) at Kennedy International Airport (KIA) during August 1974 through June 1975 were a continuation of the flyby tests to demonstrate system performance conducted at NASA-MSFC during January through July 1974. Because of certain nonevaluated factors such as noise from airport radar, liaison problems, etc., the test program was entered with some trepidation. However, many expected problems never materialized and the systems performed very well. In particular, during the first three months of tests, very few component failures occurred and the systems were always operational when the runway was in use. During the second phase of operations, a few power supplies and integrated circuits had to be replaced. By that time, many hours of operation had been logged on essentially breadboard equipment. The operation became mostly routine and some special tests were run such as frequency translator evaluation tests and long range vortex detection using the FAA's Convair 880 as the vortex source.

A total of 1619 data runs was recorded with a totally operational system during normal landing operations at KIA. In addition, 53 data runs were made during cooperative flybys with the C880 for a grand total of 1672 recorded vortex tracks. Test crews were in attendance at KIA for 31 weeks, of which 25 weeks were considered operational and the other six were for packing, unpacking, setup and check out. Although average activity equates to 67 recorded landing operations per week, two periods of complete runway inactivity spanned 20 days and 13 days, respectively. The operation frequency therefore averaged about 88 operations per week.

The breakdown of the report and a brief discussion of the various sections follows:

Section 2 discusses the site installation and set up at Kennedy International Airport of the Scanning Laser Doppler System (SLDS) along with support services.

Section 3 describes the system calibration and operation procedures used for initial setup and for day-to-day operations. Complete procedures are outlined along with operational data handling which is presented in Section 4.

Section 5 discusses the hardware evaluation including system performance, breakdowns, repairs and recommendations for future systems.

Appendix A contains test summaries for days when data were collected while Appendix B is a complete cross reference of data with aircraft type, wind conditions and run numbers.

Section 2
SITE INSTALLATION

The test site at KIA was prepared by NAFEC personnel prior to the arrival of the SLDS. Portable aluminum pads (Fig. 1) were laid on the surveyed site approximately 400 ft outside the middle marker and 400 ft either side of the runway centerline. Power transformers (Fig. 2) were installed near each pad with 220 Vac, 100 amp service for Van 1 and 60 amp service for Van 2.

The vans were transported via tractors from Huntsville to a Lockheed Aircraft Services (LAS) building located at KIA. Lockheed-Huntsville personnel arrived on 26 August 1974 to begin setting up the system. Local riggers were subcontracted to transport the vans from the LAS hangar area to the test site and to locate and block-up the vans on the pads. Due to soft sand and rugged terrain a crane was required (Fig. 3) to place Van 2 (Fig. 4) in position. An electrical contractor installed ground rods (four per van, 30 ft deep) and connected the power to the vans.

On 29 August the first plane load of equipment was received at KIA. The four-wheel drive truck provided by NASA proved invaluable in transporting the equipment from the LAS hangar area to the test site. On 31 August the equipment for Van 2 arrived and was transported to the site. By 2 September most of the equipment had been unpacked and installed in the two vans. Final alignment and calibration of the laser system were completed by 7 September.

A safety corridor (Fig. 5) was set up between the two vans. This area was roped off, equipped with red warning lights which were activated when the calibration wheels were on, and appropriate laser warning signs were installed. Cables were run in this corridor between the two vans for

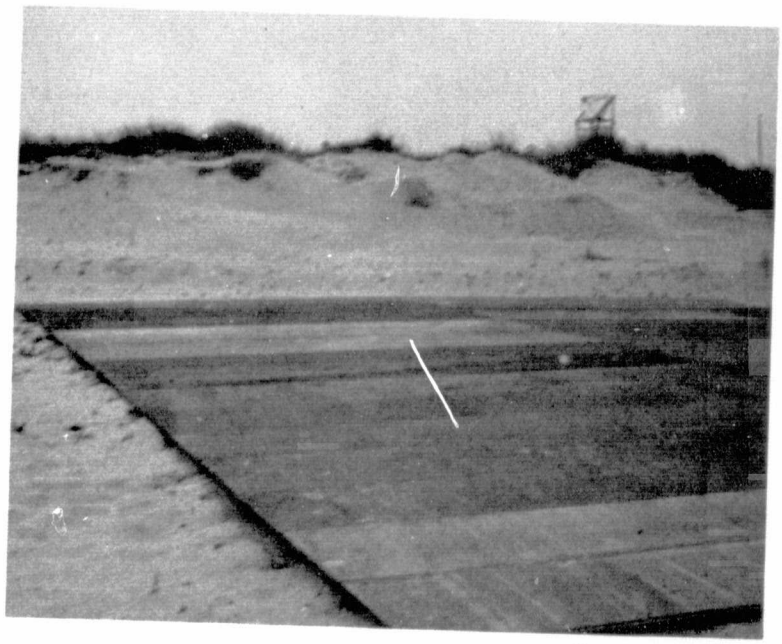


Fig. 1 - Aluminum Pad for SLDS No. 2 Unit

Fig. 2 - Pad and Power Transformer for the No. 1 SLDS Unit

Fig. 3 - Lifting Van 2 in Place at KIA (28 August 1974)

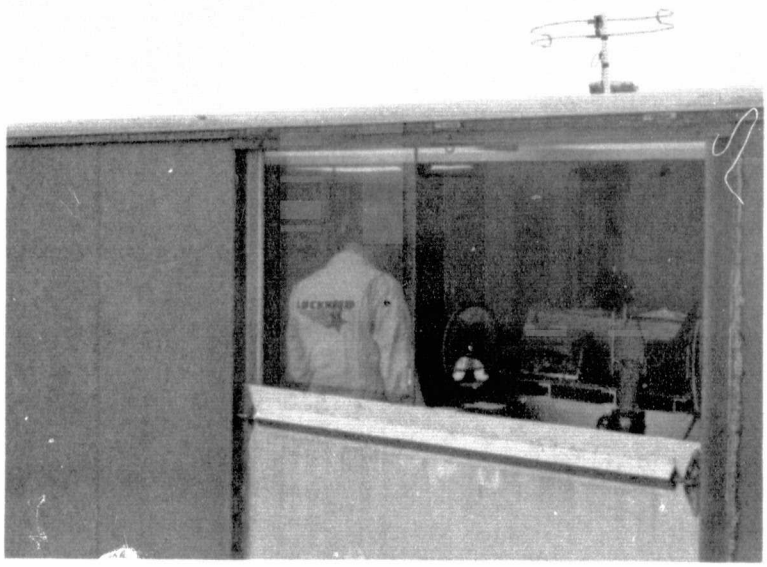


Fig. 4 - Van 2 in Place and Operating at KIA

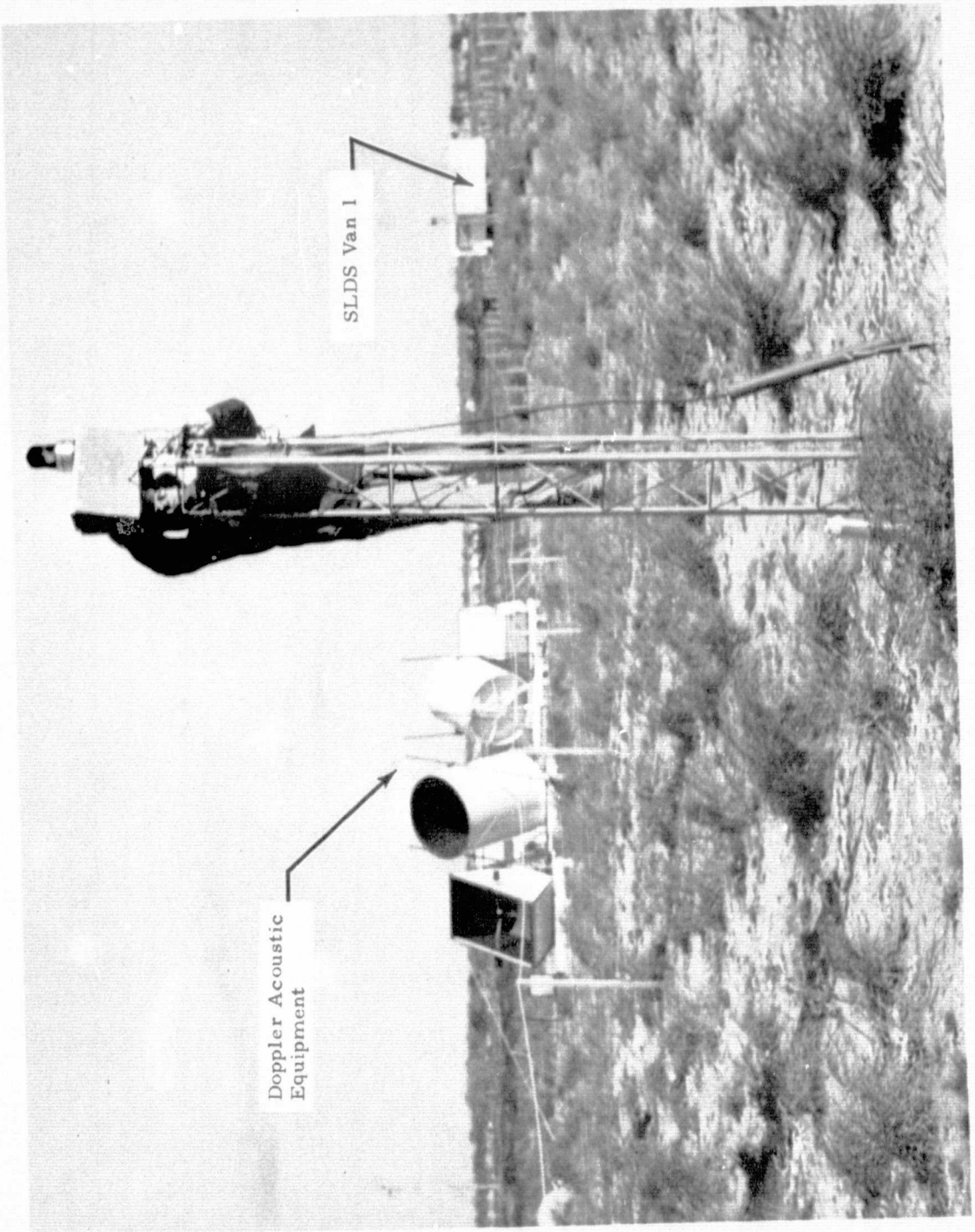


Fig. 5 - Safety Corridor Between Vans Containing Calibration Towers

communication and computer input data transfer. The cables were buried to prevent damage by rodents and to minimize lightning damage to equipment.

Enclosed calibration targets, spinning sandpaper wheels (Fig. 5), were installed on eight-foot towers at a distance of 560 ft from each van.

The assembled site external geometry is depicted in Fig. 6. Several weeks after arrival at KIA it became apparent that an office area would be helpful for preparing data, repair of equipment, and storage. The Transportation Systems Center (TSC) happened to have a spare house trailer at KIA and offered its use for the duration of the program. The trailer was immediately moved to a location adjacent to the middle marker and set up. Telephone service and intercoms were then installed between the three vans. A Xerox machine was leased and became a much used piece of equipment as each data sheet and hard copy was reproduced in quadruplicate.

Local vendor sources were established immediately upon arrival in the KIA area. This included electronic and mechanical hardware, liquid nitrogen service, and equipment manufacturers such as Hewlett-Packard, Tektronix, etc.

Lockheed Electronics Company (LEC) in nearby Plainfield, N. J., provided equipment calibration and repair service. LEC personnel would pick up and deliver and offered a two to three day turnaround on servicing. One other item which helped logistically was the acquisiton of a station wagon and van from the local Lockheed Aircraft Service (LAS) office. Both vehicles were equipped with New York Port Authority tags and required no escort on the airport or when crossing the runways.

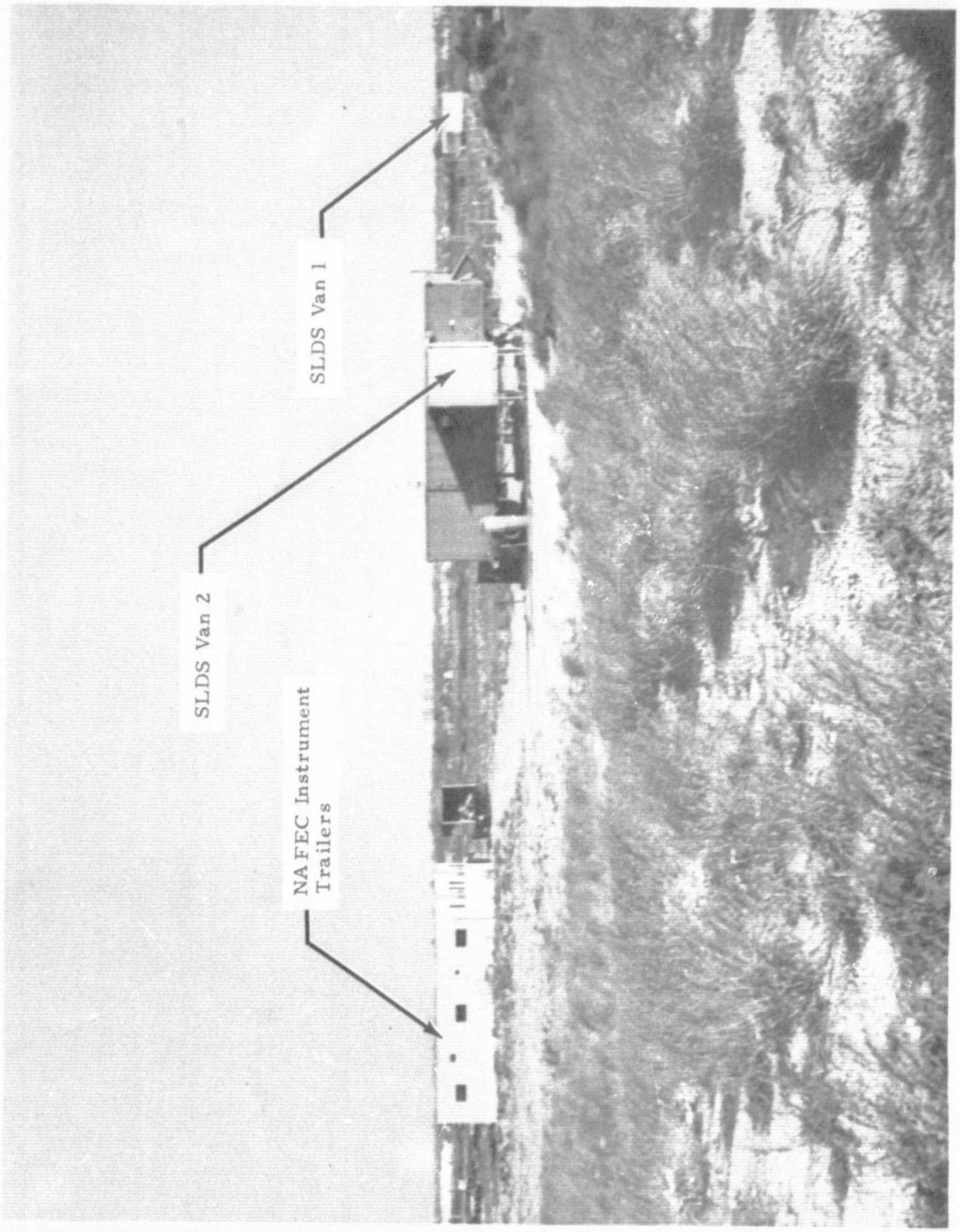


Fig. 6 - Site External Geometry

Section 3
SYSTEM CALIBRATION AND OPERATING PROCEDURE

3.1 SYSTEM CALIBRATION

Calibration of the system is divided into two categories: (1) equipment calibration, and (2) system performance calibration. Major calibration of instrumentation was performed at selected intervals while performance calibration was performed several times daily.

3.1.1 Equipment Calibration

Upon arrival and installation of equipment at KIA all electronic hardware was tested and checked out. The FR 2000 tape recorders were damaged in shipment and were not operational when installed, with both recorders having non-operational channels. Lockheed Electronics in Plainfield, N. J., was called in to check out the systems. By interchanging hardware, the Van 1 recorder was made operational. However, some components were bad in the other system. Through LEC a Tekronix service representative removed the bad cards and either repaired or replaced the bad components. Fortunately, most of the repairs were covered under warranty. Within a week both units were operational and both were completely calibrated by the Tektronix representative. All other equipment; scanners, processors, scopes etc., were calibrated by the Lockheed or Raytheon field engineers. The equipment was monitored daily and was recalibrated at the first sign of discrepancy. Following the brief shutdown of operations from 20 December to 4 March, the equipment was checked thoroughly upon reactivation. One Lockheed engineer remained on site and periodically operated the equipment during the shutdown. This may have prevented any major deterioration in the equipment.

The computer system, although operated by Lockheed personnel, was maintained by M&S Computing. For the most part no major problems arose within the system.

3.1.2 System Performance Calibration

The calibration of the system consisted primarily of calibration of the range scanning mechanisms. Due to the inherent physics involved, the range is not directly measurable within the van although one could possibly use a stable jig to physically measure the distance from the primary to secondary mirror. To dynamically check the calibration, a fixed hard target was located at an accurately known distance from the system. To statically set the range a micrometer was adjusted to peak the singal after the scanner had been set at the desired range. While the system was peaked for range, signal-to-noise ratio and other measurements were made with the LDV. To dynamically calibrate the range, the range scanner was activated which scanned the beam focus through the target. The signal processor was then set at a high amplitude threshold where only the peak of the signal was visible. The computer would at this time calculate the range at which the peak intensity occurred. These results were printed in graphical and tabular form. The computer would also calculate standard deviation and mean range. This works very well when the system is stable, however, if the threshold is too low or if there are few points, the apparent location of the range changes. Since the processor operates in a linear mode (not in log mode as does the spectrum analyzer) the peak can fluctuate drastically due to small instabilities in laser output, alignment, etc. When the system was stable it was possible to obtain measurement with a standard derivation of 1 foot at exactly 560 feet.

The other calibration measurements were actually part of the operating procedure and consisted of measurements of noise and of the wind recorded at the beginning and end of each analog tape as a measure of system performance for that day. However since the systems did drift over a period of time and occasionally had to be tweaked during data gathering, the performance at any one instant of time cannot be ascertained other than by examining the

signal-to-noise ratio (S/N) of the vortex on wind. For the most part, the variations were not drastic and did not unduly affect performance.

3.2 OPERATING PROCEDURE

After the first two weeks of operation a routine was established which was followed throughout the test program.

Upon arrival at the site if it appeared that the runway would be in use and no major maintenance was scheduled, the test crew began preparation for data collection. The two lasers were turned on immediately to allow a 30-40 minute warmup period. During this period the detectors were filled, calibration wheels uncovered, turned on, and electric equipment turned on for warm-up. This also allowed time to finish reproduction of data collected during the preceding day.

3.2.1 Laser Setup

When the lasers were sufficiently warmed up and stabilized the laser operator began alignment checks. This consisted of first adjusting the laser power to maximum ($\sim$ 15 watts) at the telescope secondary. Then the power meter was removed and the telescope alignment checked, particularly the beam position on the secondary mirror. This alignment was adjusted by the mirror which directs the beam into the telescope. Next the alignment of the local oscillator leg is verified by adjusting for minimum voltage level on the detector. The system was "tweaked" by adjustment of the folding mirror and aperture until the predetermined optimum power levels were achieved. At this time the L.O. was blocked as the backscatter from the secondary was used to check the alignment of the signal leg of the interferometer. Occasionally when performance was degraded the recombination alignment was checked by visually superimposing (using thermal paper) the L.O. and return beams at the detector. The wire was then inserted in front of the secondary and adjusted by using the maximum voltage level on the detector to indicate minimum power backscattered. At this point the system was aligned onto the

wheel by adjusting the output mirror. Once the wheel was found the range was adjusted for maximum S/N.

In order to verify proper alignment the recombining beamsplitter was adjusted for maximum S/N and minimum fluctuation of signal. Fluctuation indicated improper alignment of L.O. and signal beams. At this point the S/N was checked and all data recorded. The system was then ready for calibration tests.

While the laser system was being aligned, the electronics and computer systems were set up. In preparation for the calibration measurements the scanner was set up for 172 meter range (560 feet) with the elevation locked at 0 degrees and the processor setup by inserting a 60 dB attenuation to prevent the LDV signal from overdriving the processor.

The calibration tests are outlined in detail in Section 3.1 and briefly consist of the following:

- Range Calibration

This is accomplished by scanning the beam at normal scan rates through the wheel. These data are recorded on both the analog recorder and the computer. The computer plots the wheel position graphically and points out the location and standard derivation along with number of data points. The processor amplitude threshold is adjusted such that only the peak signal is allowed through the system. Variation in threshold changes the peak location. While the system was running the laser operator adjusted the range scan micrometer in order to obtain a range reading as close to 560 feet as possible. The goal was always a range of 560 feet and a standard derivation of 1 foot.

This calibration was the most critical and often most time consuming of operations particularly for two vans in operation. Normally 30 minutes to an hour was required.

- Performance Calibration

Following range calibration the systems were run through several modes in order to record background information to be used later in post analysis. This was only recorded on analog tape. The system was reconfigured to normal scan modes and the attenuation removed from the processor. The scanner was setup as follows: range 063 to 250 meters at 6.5 Hz, and elevation 3 to 33 deg. at 0.2 Hz. The processor was set up with a noise level of 32 and a velocity threshold of 1 or 2. With the window closed, a 30 second segment of tape was run to record the systems noise level. Then the window was opened for another 30 second run of ambient wind signals. At this point the system was ready for aircraft flybys.

3.2.2 Flight Operations

Three people were normally required in Van 1 to operate the system. These consisted of: (1) laser system operator, responsible for proper laser operation while assisting with data sheets and analog tape recorder; (2) electronics system operator, who set up the processor and scan system, time code and log sheets; and (3) computer operator who spotted aircraft and directed start and stop of recording equipment. Van 2 required only two operators. When flight operations were being recorded operators were in constant communication via intercom headphones.

Following calibration tests the systems were reconfigured as follows: The processor noise level was set at an amplitude of 64 corresponding to 12 dB by setting the velocity threshold high enough to eliminate all wind signals then adjusting the input level until random false alarms were occurring about 5% of the time. The amplitude threshold was then set to approximately 74 or $\sim$ 2 dB above the noise floor depending on aircraft type and was sometimes adjusted by the operator according to S/N, wind conditions, etc. The velocity threshold was set as low as possible, usually about two cells above the maximum wind velocity.

Prior to the first recorded data and at various times throughout the data gathering, the wind velocity and amplitude were measured. Velocity was measured by adjusting the velocity threshold to locate the cell at which the peak amplitude occurred which was recorded on the data sheet. The wind signal amplitude was determined by first lowering the velocity threshold to 1 then increasing the amplitude threshold until just a few false alarms occurred on the display. This value, normally 165 to 199, varied day to day depending on laser performance, atmospheric pollutant level, etc. Following these checks the processor was returned to the flight settings and the run number set for the first flight.

3.2.3 Computer

The operational procedures for the PDP-11 are as follows:

1. Turn power on and let the system warm up for 15 minutes
2. Insert the BCD code of 773010.
3. Load the production and data disk in their respective units.
4. Start the two disk units by placing them in the run position.
5. Depress the halt switch, then flick the start switch to insert the program into the computer, raise the halt switch and start the computer.
6. The program code appears on the Tektronix 4014 terminal display.
7. Type in MOU DK1, then insert the time, Run W2EFS and, Run VIXI or VIXV depending on the algorithm desired.
8. Mode selection of real time, post analysis, wind and termination will appear on the screen. Select desired program program with the cursor.

    a. Real Time: Program displays real time data collection

    b. Post Analysis: Program includes scatter plots, debug, and the option to review the real time data collected.

    c. Wind: Program is run with both LDV systems scanning.

d. Termination: Procedure at the end of each day which puts two end of files on the digital tape and two disks so that cueing to that tape position is readily performed.

9. If real time is selected with the cursor, the next portion of this program will appear on the display. It allows the insertion of day, run number, and the type of visual display desired. After selecting the right format, aircraft ID is selected. The parameters for each type of aircraft are already programmed into the computer.
10. At the end of the last data run, and end of file is put on the digital tape and the disks, this brings up mode selection on the display, termination end of file on the tape and disks, and rewinds the digital tape.
11. Power shutdown daily procedure for calibration of the LDV systems.

The computer is operated in the normal mode except during aircraft ID selection. WHEELS is typed in, which is the program selection for calibration. This program requires 30 frames to calculate range to hard target and the standard deviation which are used in verifying the LDV system performance.

3.2.4 Data Recording Sequence

With all systems up the actual data recording sequence went as follows:

1. Computer operator spotted approaching aircraft at approximately 10 miles from airport. Operators prepare for recording. Tower is monitored for wind conditions which are recorded.
2. Positive identification of aircraft type is determined by engine layout, flap arrangement, and at night — landing light configuration.
3. Computer operator enters aircraft type. Amplitude threshold may be adjusted on processor.
4. At 30 seconds analog tape recorder is started, reset button activated on processor at which instant the time code is read and recorded on data sheet.
5. Computer is started at 5 seconds prior to flyby.
6. During the recording of the vortex signals the computer display is monitored. Notes are made as to quality of

track information, length of run etc. The computer operator then informs the other operators when signals no longer occur.

7. When the vortices have dissipated or traveled beyond the scan area, the analog tape and computer are stopped and time code recorded.
8. The system is reconfigured for the next approaching aircraft.

After the first aircraft flyby the operator uses the information gathered from the computer display and processor display to improve the system settings for subsequent aircraft. The processor thresholds may be adjusted up or down as required, and the scan limits may be changed depending on the direction and velocity of the crosswind component. After about five aircraft have been recorded the system is pretty well optimized for the prevailing conditions. Over a period of several hours the condition may change and therefore the system is carefully monitored throughout the data recording session.

A typical day consisted of about 50 aircraft over a four-hour period starting about 1300 hours. When the day's runs were over, usually by the switching of runways or when aircraft landings were more than 30 minutes apart, the system was prepared for shutdown.

The calibration runs were repeated and included wind signal, noise measurement and wheel signal. When all was on tape the laser system and electronics were shut down and the analog tape rewound and removed. The computer tape was rewound and removed. During the second phase of operations when the second disk had been installed, up to 200 runs were recorded on the second disk, usually a weeks testing. At the end of the week the disk was dumped to tape and the tape sent to TSC along with copies of the data sheets.

As outlined previously, the warmup, calibration, and preparation for flight tests occupied about two to three hours, depending primarily on the length of time required to achieve acceptable range calibration measurements. Several problems were encountered which were not always successfully overcome.

Repeatability of range calibration seemed to be somewhat random, some days being very good and others almost impossible to achieve. Van 1 fluctuations were overcome by maintaining as stable an internal van temperature as possible. After the Teflon window was installed the system operated much more reliably. The cooling systems of the van was inadequate to cope with all the equipment and personnel usually in the van. With the windows open, wind blowing through the van caused the system to fluctuate. Van 2 suffered from laser problems which affected alignment at times. During the latter period of operation the range calibration was repeated approximately every hour to check or adjust the range. However, there were almost no flight days on which both systems were down. Normally Van 1 was always up. Late in the test program a series of experiments with the translator were run with Van 2. Many problems were encountered and much was learned from the tests.

Section 4
DATA HANDLING

On-line data output of the system at KIA consisted of analog tapes from both laser systems, digital tapes from the combined computer output, data sheets from each system, and hard copies of the computer display.

The typical output from one day's data of 60 data runs plus calibration included: four analog tapes (two each from each LDV system containing approximately 30 runs each); two digital tapes (one for NASA post-analysis and one for TSC); 10 data sheets (four each from the LDV systems and two from the computer); and approximately 170 hard copies.

To provide copies of the data, a Xerox machine was leased and at the end of each day the data were copied, compiled, and bound in a notebook. A total of four copies were made of the data sheets (~ 720 pages). Copies were provided for NASA, Lockheed, Raytheon and TSC, with the originals filed at the test site.

Periodically, the analog tapes, digital tapes and a set of data sheets were packed and sent to MSFC for analysis. At the end of each week the extra digital tapes and a set of log sheets were delivered to the on-site NAFEC representative who shipped the data to TSC.

Occasionally for special tests or when computer program updates were incorporated, on-line analysis was performed. These data were usually shipped or hand-carried directly to MSFC.

Section 5
HARDWARE EVALUATION AND CONCLUSION

5.1 INTRODUCTION

In general, the system performed remarkably well. There were, however, system components which malfunctioned from time to time. In many cases, problems arose which were permanently corrected. Some pieces of equipment exhibited operational failures which occurred in a random fashion and could not be predicted or corrected to prevent future difficulty. A few system components could be modified or replaced with next generation instruments to increase reliability, reduce maintenance and manpower requirements, and create a more completely automated system.

Many component failures were a direct result of the large temperature extremes (60 to 90 F) inside the van (especially Van 1). It was amazing that at elevated temperatures as much operational success and continuous operation was consistently achieved.

5.2 TELESCOPE

A discrepancy often occurred between wheel calibrations performed at the beginning of test runs and at system shut down. It was determined that this variation was in large part due to thermally induced relative length changes in the aluminum structure supporting both the primary and secondary mirrors in the telescope. As ambient conditions in the vans changed the aluminum tables expanded and contracted in length along the optic axis of the telescope. Although this calibration error can be taken into account and compensated for in data analysis, it is preferable to eliminate it altogether.

The optimum solution to this problem involves fabricating a structure to separate the primary and secondary mirrors out of material which exhibits

minimum sensitivity to ambient thermal excursions. A feasible and cost effective structure incorporating this capability could be constructed of invar rods to act as spacers between primary and secondary mirrors. In the next generation LDV system, this low expansion telescope feature could eliminate one calibration step and promote a higher degree of system automation.

One optical problem which occurred periodically involves backscatter of the laser beam back into the detector. This saturates the detector and decreases its sensitivity. The technique used to reduce backscatter involves placement of a thin wire ahead and spatially adjacent to the secondary mirror. On-axis radiation is diffracted in such a manner that most of the on-axis radiation never reaches the detector. To minimize the backscatter, the position of the wire is adjusted such that the voltage reading on the bias meter is maximized. In numerous cases, a double maximum due to diffraction effects was obtained. Optical system realignment to remove this effect was attempted with varying amounts of success each time this phenomenon occurred. Concurrent with observation of this double peak, a large scatter (standard deviation) in wheel calibration range measurement was present.

Later tests were conducted at Lockheed-Huntsville which found the double peak phenomenon to be caused by slight multi-moding of the laser causing essentially two apparent beams to be combined on the detector. This can be eliminated by a more stable laser, better tuning of the laser, of deliberate misalignment of the detector so that only one mode is sensed by the detector. This last method is not recommended as the signal level is necessarily reduced.

5.3 LASER

The laser should be considered to be the central component problem if the major goal is to develop a self-sufficient, reliable, automated, LDV optical system. The CO_2 laser used in these experiments operated with few failures, i.e., it seldom failed to operate, but required almost constant attention and

optical adjustment by the operator to maintain its alignment and keep its power within acceptable limits. Performance of the laser in Van 1 was, in general, considerably superior to the unit in Van 2 in both power output and power stability, however, both were found to fluctuate by as much as ±15% over several hours operation. Figure 7 presents plots of power fluctuation. As long as a qualified operator is present to maintain both laser and optical systems alignment, the laser presently in use is satisfactory although not optimum. If, however, an unattended system were envisaged, the present laser is totally unsatisfactory.

Laser warmup time, until adequate power stability was obtained for operator assisted operation, ranged from 30 minutes to several hours, with the Van 2 laser always requiring longer warmup time. The warmup time for both lasers was decreased by the installation of resistance type radiant heaters employed to keep the temperature of the vans constant during overnight outside temperature excursions.

Current fluctuation problems developed with a laser power supply in Van 2 and were partially corrected when a resistor was replaced in the voltage range adjustment switch. This repair improved current stability (and hence laser power stability), but did not entirely remove the current fluctuations. A new power supply was installed. Problems occurred also with this supply. Later it was discovered that the major problem was arcing in the high voltage multi-pin connector at the base of the power supply rack.

The water cooling system and its associated interlock and warning system (buzzer) performed well as long as the water reservoir was full after an initial adjustment was made to the fluid relay interlock. Initially, the pressure setting of the relay was set too high and since the pressure at the sensor point in the fluid cooling system was not adequate, the interlock did not close, the high voltage section of the power supplies would not start, and the buzzer would indicate a cooling system problem.

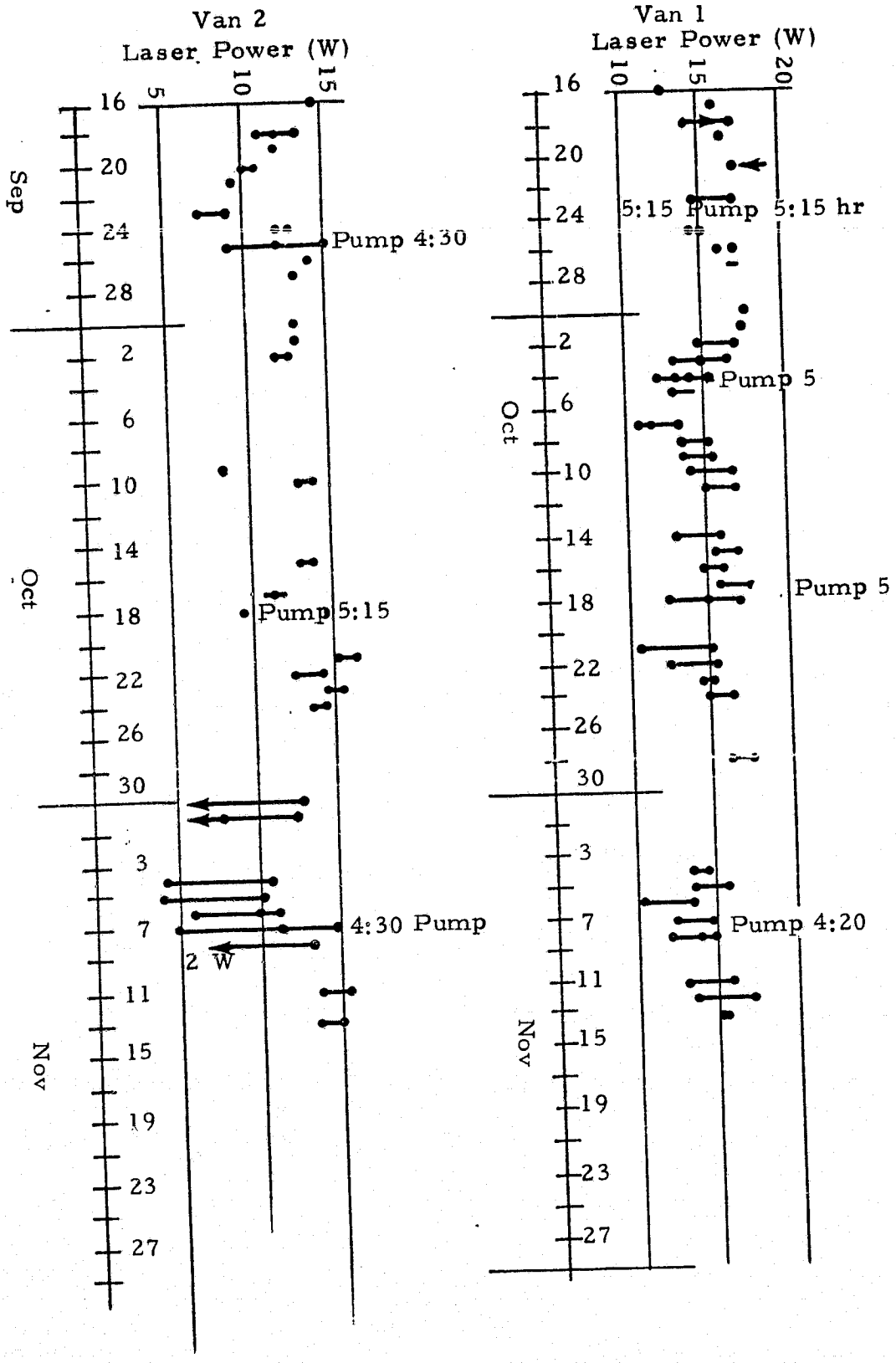


Fig. 7 - LDV Laser Power Measured at Secondary — Maximum and Minimum During Each Day of Operation for Period Indicated

Laser power stability and pointing stability are interrelated. If the power of the laser remains constant and the pointing vector coincident with the laser beam "wanders," i.e., changes direction from some initial fixed position, the interferometer must be readjusted to regain the same LO power level incident on the detector. Usually, as the pointing stability degrades, the power also falls off. In this case, both the laser and the interferometer must be realigned. A more stable laser both in power and pointing would reduce the problem considerably.

Alignment of the laser involved rotating differential screws which are an integral part of the optical mirror mounts for the laser cavity. These screws were machined from brass and inserted into brass and stainless steel threads. After considerable operational use the threads would gall and the adjustment screws would "lock up," (seize) and become inoperable. This prevented optimization of laser power. These differential screws were replaced with duplicates, the laser realigned, and operation continued. It would be preferable to make these elements from stainless steel or invar (a low thermal expansion material).

It was quite evident that laser operation is quite sensitive to ambient thermal conditions. This source of instability could be removed by utilizing a hermetically sealed, temperature controlled laser case.

5.4 RANGE AND ELEVATION SCANNER

5.4.1 Mechanical Structure

Mirror problems associated with the range scanning mechanism of the telescope included: (1) cable slippage, resulting in range calibration errors; (2) mirror-wire collision, due to transients in the electronic circuitry (this damages the mirror surface due to deposition of carbon black); and (3) secondary mirror mount vibration which causes range calibration fluctuation (jitter). The first problem can be corrected by tightening the cable clamp, the second by

installing a mechanical stop on the secondary shaft and elimination of spurious electronic servo signals, and the third by adding a clamp to the mount to increase mechanical rigidity.

5.4.2 Electronics

Most scanner electronics malfunctions were due to component overheating. After presumed thermal effects caused failure of several components such as binary counters and rate multipliers, a fan was installed to reduce the component temperature. This greatly reduced the rate of component failure. In addition to heat associated component failure, power failure and power line fluctuations can be blamed for other integrated circuit malfunctions.

5.5 MACH-ZEHNDER INTERFEROMETER

The interferometer in general operated very well. It did, however, require considerable periodic realignment in the local oscillator/detector leg of the optical train. This should not be construed to be a fault of the interferometer. The pointing and power instabilities of the laser were probably the dominant factors affecting the necessity for this adjustment. The interferometer base is fabricated from aluminum which exhibits a strong thermal expansion characteristic. A more suitable material for this plate would be stainless steel, invar, cervit or ULE quartz in order of increased preference (stability).

A modification was made to the interferometer on-site when a variable aperture (iris) was added adjacent to the half wave plate in the local oscillator path to allow control of the LO power incident on the detector independent of the aperture preceding the detector focusing lens. This additional aperture was inserted since use of the detector aperture varied signal power on the chip as well as LO power. After installation of this element, as long as the laser power was sufficiently high, fixed detection bias settings could be maintained without changing the Doppler signal level. The power on the chip could be kept constant simply by adjusting the new aperture.

5.6 DETECTOR

The HgCdTe detectors performed well. Their quantum efficiencies are, however, lower than that of some PbSnTe detectors presently available. The optical surface of the dewar window appeared degraded in the visible spectrum, but evidently was adequate at 10.6 microns. This conclusion was reached after the window was replaced with a new CdTe optic, dewar re-pumped, and performance remained unchanged.

The only other detector problem involved cooling. Depending on ambient conditions, the hold time of the dewar varied around a median of approximately 30 minutes before refill was necessary. A self-contained, low maintenance, closed cycle detector cooling system is needed to eliminate this drawback and increase system capability and reliability.

The detector bias circuitry underwent minor modifications in an attempt to improve performance and prevent accidental detector damage. This included installation of more optimum impedance matching transformers, over-voltage protective diodes, and an isolated meter circuit.

5.7 FREQUENCY TRANSLATOR

The frequency translator was installed on the interferometer plate and aligned. It was attached to a mount (positioner) capable of rotation about the vertical and translation along orthogonal axes in the horizontal plane. The mount proved to be totally inadequate since it could not maintain a stable directional orientation, i.e., it drifted in position. It should be replaced and hard mounted (bolted) to the interferometer base plate. Even with a good stable mount the translator is difficult to align, very sensitive and tends to drift off its optimum operating point.

The heat load on the acousto-optic crystal due to RF driver input power or partial laser beam absorbtion can cause optical throughput fluctuations. This is not a major consideration at low power levels and presents only a minor problem since the low RF driver power range is presently used.

Another problem associated with the translator is the apparent fluctuation of power as indicated by the detector bias meter. This fluctuation can be attributed to one of three things (or some combination of all): short term power fluctuations in the laser, mechanical instability of the translator mount, or RF power fluctuations from the driver electronics.

Some attempt was made to isolate the problem with no conclusive result. The fluctuations appeared to be of shorter duration than those normally associated with the laser. Also, mechanical realignment seemed to produce only intermediate success. This led to the third possibility of fluctuation of the RF driver. Future effort should be directed toward solving this problem.

5.8 SIGNAL PROCESSOR

The signal processor suffered several intermittent major breakdowns and numerous intermittent malfunctions. Its overall performance, however, was satisfactory for this application. Power supply (5 V) failure accounted for the major breakdowns whereas component overheating resulted in short term unit malfunction. The unit was pulled out from the rack during periods of high ambient temperature conditions to facilitate component cooling and increase run time between malfunction. Other cooling techniques such as rack blowers were also used. Numerous IC components were replaced as a direct result of overheating and power line voltage transients (and fluctuations) and electrical failure. Cooling of the processor in many instances caused equipment recovery and brought the system back on line (into operation).

5.9 COMPUTER

After an initial setup period and checkout interval, the computer performed with only a few malfunctions. Both hardware and software modifications were required to optimize the data handling system for this application. High ambient temperatures affected the computer and display equipment in a similar manner as the processor, i.e., hardware malfunction due to component overheating. In several cases IC and PC cards had to be replaced. A few problems also resulted from line transients and electrical power failure.

5.10 MISCELLANEOUS EQUIPMENT ITEMS

5.10.1 Data Display Units

The primary display unit and graphics table malfunctioned several times due to overheating. Cooling these elements usually enabled operation to be resumed.

5.10.2 High Speed Tape Recorders

The tape recorders performed without failure for most of the tests with the exception of the unit in Van 2 which stalled several times near the end of the testing program. This defect was corrected.

5.10.3 Copiers

A persistent and annoying problem which occurred with regularity involved paper jamming in the electrostatic hard copy units. Considering the thousands of copies produced, however, their performance record was not altogether unsatisfactory.

5.11 RECOMMENDATIONS FOR FUTURE SYSTEM

5.11.1 Laser

- 20 W output
- Excellent frequency and amplitude stability
- Acoustic and vibration isolation
- Temperature stability — warmup time: 1/2 hr
- Quartz or CERVIT cavity
- Small power supply, current controlled
- Rechargable or flowing gas
- Compact ~ 48 x 10 x 7 in.
- High reliability
- Field serviceable

5.11.2 Optics

General — package should be integral design, possibly tubular invar framework for laser, interferometer, and telescope — compact environmentally controlled package.

Interferometer

- Mounted on invar plate, off-shelf "Klinger" mounts incorporate spotting scope
- Basic M-Z as now in use

Telescope

- 12 in. diam. f/2
- Secondary separated by invar

Translator

- Tellurium crystal — 5 W input power
- Develop notch filter
- 3 kHz wind — 300 kHz vortex
- Small size

5.11.3 Detector

- Pb:Sn:Te with multiple chips
- Closed cycle cooler
- Transimpedance amplifier

5.11.4 Scanner

- Multi-mode scan capability — VAD plus elevation and azimuth
- 12 x 24 in. lightweight mirror
- Integrate into package design — weatherize
- Teflon window, heater/blower inside, window wiper

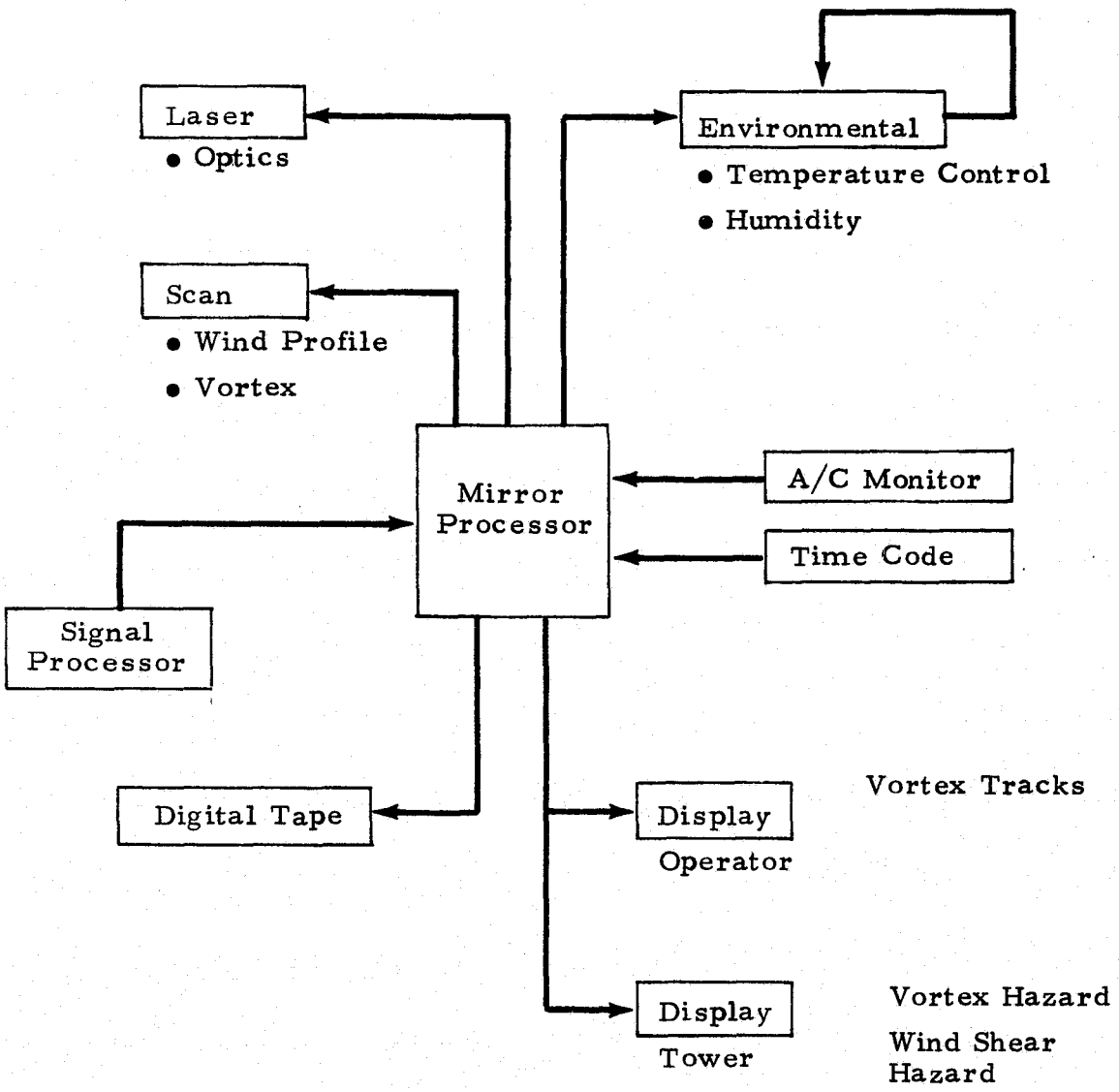
- Control for: range; amplitude; cone angle; elevation; wind profile
- Possibly microprocessor controlled if tracking required
- Operate in wind shear mode

5.11.5 Processor

- Simplified delay line with adaptive threshold

5.11.6 Data Reduction Control

- Microprocessor controls scan, monitors laser power, bias voltage and current, laser temperature
- On-line reduction of wind profile information
- Vortex information
- Controls digital tape — one to two minute intervals for wind profile; up to three minutes for vortex


Laser
• Optics
Environmental
• Temperature Control
• Humidity
Scan
• Wind Profile
• Vortex
Mirror Processor
A/C Monitor
Time Code
Signal Processor
Digital Tape
Display
Operator
Vortex Tracks
Display
Tower
Vortex Hazard
Wind Shear Hazard

Appendix A
TEST SUMMARIES

Appendix A

The following test summaries for each test day contain the number of aircraft types recorded during day, times and wind condition. Problems occurring during tests and a subjective determinator of the quality of data were made in real time.

Day: 266

Rating: Fair

On 9-23-74, testing occurred between the hours of 14:34 and 16:56 for a total testing time of 2:21. Total number of runs for the day were 53 with both van(s) operating. Excellent run(s) of the day were none

Aircraft included:	B-707-15	B-727-9
	B-737-0	B-747-13
	DC-8-8	DC-9-3
	DC-10-2	L-1011-1
	VC-10-0	BAC111-0

and 2 miscellaneous aircraft. Wind conditions varied between N/A[1] and N/A knots over N/A° to N/A° . Signal to noise measurement was 58 to 57 for Van 1 and 52 to N/A for Van 2. Range location for Van 1 varied from N/A ft to N/A ft and Van 2 varied from N/A to N/A ft.

No problems occurred on this day.

Day: 270

Rating: Fair

On 9-27-74, testing occurred between the hours of 10:18-12:14 and 13:42-14:05 for a total testing time of 2:19. Total number of runs for the day were 27 with both van(s) operating. Excellent run(s) of the day were none.

Aircraft included:	B-707-9	B-727-4
	B-737-0	B-747-0
	DC-8-2	DC-9-6
	DC-10-0	L-1011-0
	VC-10-1	BAC111-0

1. N/A — Not available.

and 5 miscellaneous aircraft. Wind conditions varied between N/A and N/A knots over N/A° to N/A°. Signal to noise measurement was 61 to N/A for Van 1 and 54 to N/A for Van 2. Range location for Van 1 varied from 663 ft to N/A ft and Van 2 varied from 581-566 to N/A ft.

Problems: A 40[illegible] dB input amplifier in the processor went bad in Van 1.

Day: 273

Rating: Fair

On 9-30-74, testing occurred between the hours of 15:57 and 16:09 for a total testing time of 12:23. Total number of runs for the day were 8 with both van(s) operating. Excellent run(s) of the day were none.

Aircraft included:	B-707-1	B-727-2
	B-737-0	B-747-3
	DC-8-1	DC-9-1
	DC-10-0	L-1011-0
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between N/A and N/A knots over N/A° to N/A°. Signal to noise measurement was 57 to 61 for Van 1 and 55 to N/A for Van 2. Range location for Van 1 varied from 572 ft to N/A ft and Van 2 varied from 544 to N/A ft.

Problems:

1. It was found that there appeared to be an overlap of data between frames. It was determined that this was caused by the use of the command signal for the turn around from the scanner to start a new frame in the computer. The command signal leads the actual turn around of the mirror by approximately 4 seconds. A circuit is now being designed which will correct this problem.

2. A power failure occurred that shut down the whole site due to a small fuse in the main power lines for the site at the power station.

Day: 275-1

Rating: Good

On 10-2-74, testing occurred between the hours of 10:58 and 13:06 for a total testing time of 2:08. Total number of runs for the day were 14 with one van(s) operating. Excellent run(s) of the day were 1, 4.

Aircraft included:	B-707-2	B-727-4
	B-737-0	B-747-1
	DC-8-2	DC-9-2
	DC-10-2	L-1011-0
	VC-10-0	BAC111-0

and 1 miscellaneous aircraft. Wind conditions varied between N/A and N/A knots over N/A° to N/A°. Signal to noise measurement was N/A to N/A for Van 1 and 54 to N/A for Van 2. Range location for Van 1 varied from 567 ft to N/A ft and Van 2 varied from N/A ft to N/A ft.

No problems occurred on this day.

Day: 275-2

Rating: Good

On 10-2-74, testing occurred between the hours of 16:37 and 18:07 for a total testing time of 1:29. Total number of runs for the day were 30 with one van(s) operating. Excellent run(s) of the day was run 3.

Aircraft included:	B-707-9	B-727-6
	B-737-0	B-747-3
	DC-8-6	DC-9-1
	DC-10-3	L-1011-1
	VC-10-0	BAC111-0

and 1 miscellaneous aircraft. Wind conditions varied between N/A and N/A knots over N/A° to N/A°. Signal to noise measurement was 60 to N/A for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from N/A ft to N/A ft and Van 2 varied from N/A ft to N/A ft.

Problems: A 5 volt power supply in the processor of Van 2 failed and will not be repaired until October 8, 1974.

Day: 276

Rating: Good

On 10-3-74, testing occurred between the hours of 14:40 and 16:24 for a total testing time of 1:44. Total number of runs for the day were 37 with one van(s) operating. Excellent run(s) of the day was run 16.

Aircraft included:	B-707-13	B-727-3
	B-737-1	B-747-7
	DC-8-3	DC-9-5
	DC-10-1	L-1011-2
	VC-10-1	BAC111-0

and 1 miscellaneous aircraft. Wind conditions varied between N/A and N/A knots over N/A° to N/A°. Signal to noise measurement was 61 to 61 for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from N/A ft to N/A ft and Van 2 varied from N/A ft to N/A ft.

Problems: A 5 volt power supply in the processor has not yet been replaced.

Day: 277

Rating: Very Good

On 10-4-74, testing occurred between the hours of 15:53 and 17:02 for a total testing time of 1:09. Total number of runs for the day were 24 with one van(s) operating. Excellent run(s) of the day were 8, 23, 14, 16.

Aircraft included:	B-707-4	B-727-4
	B-737-0	B-747-5
	DC-8-5	DC-9-1
	DC-10-4	L-1011-1
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between N/A and N/A knots over N/A° to N/A°. Signal to noise measurement was 60 to 61 for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 567 ft to 549 ft and Van 2 varied from N/A ft to N/A ft.

Problem: A 5 volt power supply in the processor has not yet been replaced.

Day: 282

Rating: Fair

On 10-9-74, testing occurred between the hours of 11:12 and 13:48 for a total testing time of 2:36. Total number of runs for the day were 18 with both van(s) operating. Excellent run(s) of the day were none.

Aircraft included:	B-707-6	B-727-5
	B-737-0	B-747-4
	DC-8-2	DC-9-1
	DC-10-0	L-1011-0
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 4 and 7 knots over 210° to 340°. Signal to noise measurement was 61 to N/A for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 553 ft to N/A ft and Van 2 varied from 556 ft to N/A ft.

Problems:

1. The power supply for the processor in Van 2 was received and installed.

2. The delay circuitry for the frame count was built and installed in Van 1 and 2.

Day: 283

Rating: Good

On 10-10-74, testing occurred between the hours of 13:06-13:09 and 16:29-17:44 for a total testing time of 3:44. Total number of runs for the day were 24 with both van(s) operating. Excellent run(s) of the day was run 16.

Aircraft included:	B-707-4	B-727-4
	B-737-0	B-747-11
	DC-8-3	DC-9-0
	DC-10-1	L-1011-0
	VC-10-1	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 14 and 15 knots over 280° to 310°. Signal to noise measurement was 60 to 59 for Van 1 and 54 to 54 for Van 2. Range location for Van 1 varied from 569-561 ft to N/A ft and Van 2 varied from 552-554 ft to N/A ft.

Problems: M&S computing arrived to check on the computer problem. It was found that the problem was in the Tektronic 4014 terminal and not in the PDP11 system. A solution to the problem was found and an outlined procedure for correcting the problem should it occur again.

Day: 288

Rating: Very Good

On 10-15-74, testing occurred between the hours of 9:55 and 17:40 for a total testing time of 7:44. Total number of runs for the day were 116 with both van(s) operating. Excellent run(s) of the day were 10, 13, 11, 9.

Aircraft included:	B-707-37	B-727-22
	B-737-0	B-747-20
	DC-8-18	DC-9-14
	DC-10-1	L-1011-2
	VC-10-1	BAC111-0

and 1 miscellaneous aircraft. Wind conditions varied between 6 and 15 knots over 240° to 360°. Signal to noise measurement was 61 to N/A for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from N/A ft to N/A ft and Van 2 varied from N/A ft to N/A ft.

Problem: Another computer problem occurred by the operator holding down the termination key too long. This generates a 2nd interrupt which took place at the start of the next fly-by terminating the run prematurely. Software is being changed to clear the interrupt.

Day: 290

Rating: Fair

On 10-17-74, testing occurred between the hours of 11:15 and 15:33 for a total testing time of 4:18. Total number of runs for the day were 33 with both van(s) operating. Excellent run(s) of the day were none.

Aircraft included:	B-707-9	B-727-2
	B-737-1	B-747-7
	DC-8-7	DC-9-4
	DC-10-1	L-1011-1
	VC-10-1	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 10 and 15 knots over 230° to 250°. Signal to noise measurement was 59 to 58 for Van 1 and 52 to 51 for Van 2. Range location for Van 1 varied from 564 ft to 596 ft and Van 2 varied from 545 to 553 ft.

No problems occurred on this day.

Day: 294

Rating: Excellent

On 10-21-74, testing occurred between the hours of 12:02 and 17:35 for a total testing of 5:33. Total number of runs for the day were 78 with both van(s) operating. Excellent run(s) of the day were 2, 14, 15, 28, 38, 42, 46, 55, 64, 66, 69, 78, and 79.

Aircraft included:	B-707-22	B-727-11
	B-737-1	B-747-21
	DC-8-13	DC-9-6
	DC-10-2	L-1011-1
	VC-10-1	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 10 and 19 knots over 310° to 350°. Signal to noise measurement was 58 to 57 for Van 1 and 53 to 56 for Van 2. Range location for Van 1 varied from 562 ft to N/A ft and Van 2 varied from 560 ft to N/A ft.

No problems occurred on this day.

Day: 296

Rating: Very Good

On 10-23-74, testing occurred between the hours of 11:32 and 16:12 for a total testing time of 4:40. Total number of runs for the day were 51 with both van(s) operating. Excellent run(s) of the day were 2, 5, 14, 26, 37, 49, and 52.

Aircraft included:	B-707-16	B-727-3
	B-737-1	B-747-13
	DC-8-9	DC-9-4
	DC-10-3	L-1011-1
	VC-10-0	BAC111-0

and 1 miscellaneous aircraft. Wind conditions varied between 9 and 15 knots over 280° to 330°. Signal to noise measurement was 58 to 55 for Van 1 and 51 to N/A for Van 2. Range location for Van 1 varied from 566 ft to N/A ft and Van 2 varied from 557 ft to N/A ft.

No problems occurred on this day.

Day: 310

Rating: Excellent

On 11-6-74, testing occurred between the hours of 17:20 and 19:16 for a total testing time of 1:56. Total number of runs for the day were 41 with both van(s) operating. Excellent run(s) of the day were 1, 8, 9, 14, 17, 18, 19, 21, 22, 26, 35, 37, 38, 39, 40, 41, and 42.

Aircraft included:	B-707-10	B-727-5
	B-737-1	B-747-5
	DC-8-15	DC-9-2
	DC-10-0	L-1011-1
	VC-10-0	BAC111-0

and 2 miscellaneous aircraft. Wind conditions varied between 2 and 5 knots over 180° to 220°. Signal to noise measurement was 58 to 56 for Van 1 and 50 to N/A for Van 2. Range location for Van 1 varied from 569 ft to 540 ft and Van 2 varied from 562 ft to 561 ft.

No problems occurred on this day.

Day: 319

Rating: Good

On 11-15-74, testing occurred between the hours of 13:21 and 18:00 for a total testing time of 4:39. Total number of runs for the day were 81 with one van(s) operating. Excellent run(s) of the day was run 63.

Aircraft included:	B-707-22	B-727-13
	B-737-0	B-747-20
	DC-8-16	DC-9-5
	DC-10-3	L-1011-2
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 20 and 30 knots over 270° to 280°. Signal to noise measurement was 53 to 54 for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 577 ft to N/A ft and Van 2 varied from N/A ft to N/A ft.

Problems: Van 2 was down due to the installation of the translator.

Day: 322

Rating: Fair

On 11-18-74, testing occurred between the hours of 15:09 and 15:50 for a total testing time of 41:43. Total number of runs for the day were 14 with one van(s) operating. Excellent run(s) of the day were none.

Aircraft included:		
	B-707-7	B-727-1
	B-737-1	B-747-3
	DC-8-0	DC-9-1
	DC-10-0	L-1011-1
	VC-10-0	VAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 13 and 14 knots over 230° to 260°. Signal to noise measurement was N/A to N/A for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 552 ft to N/A ft and Van 2 varied from 567 ft to N/A ft.

Problems: Van 2 was down due to the installation of the translator.

Day: 323

Rating: Good

On 11-19-74, testing occurred between the hours of 10:42 and 10:56 for a total testing time of 0)13:26. Total number of runs for the day were 3 with one van(s) operating. Excellent run(s) of the day was run 1.

Aircraft included:		
	B-707-0	B-727-2
	B-737-0	B-747-0
	DC-8-0	DC-9-1
	DC-10-0	L-1011-0
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 2 and 4 knots over 220° to 260°. Signal to noise measurement was 50 to 51 for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 556 ft to N/A ft and Van 2 varied from 561 ft to N/A ft.

Problems: Attempts to record fly-bys with the translator in Van 2 proved to be unsuccessful and the system was returned to its normal configuration.

Day: 325

Rating: Fair

On 11-21-74, testing occurred between the hours of 11:25 and 14:31 for a total testing time of 3:06. Total number of runs for the day were 41 with both van(s) operating. Excellent run(s) of the day were none.

Aircraft included:	B-707-9	B-727-14
	B-737-0	B-747-7
	DC-8-3	DC-9-7
	DC-10-0	L-1011-0
	VC-10-0	BAC111-1

and 0 miscellaneous aircraft. Wind conditions varied between 25 and 35 knots over 250° to 270°. Signal to noise measurement was 55 to 54 for Van 1 and 51 to 54 for Van 2. Range location for Van 1 varied from 567 ft to 555 ft and Van 2 varied from 555 ft to 522 ft.

Problems: Alignment problems in Van 1 caused the loss of some data throughout the day.

Day: 326

Rating: Good

On 11-22-74, testing occurred between the hours of 12:28 and 16:41 for a total testing time of 4:13. Total number of runs for the day were 60 with both van(s) operating. Excellent run(s) of the day was run 59.

Aircraft included:	B-707-15	B-727-11
	B-737-0	B-747-12
	DC-8-8	DC-9-6
	DC-10-5	L-1011-2
	VC-10-1	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 12 and 60 knots over 330° to 360°. Signal to noise measurement was 55 to 54 for Van 1 and 51 to 54 for Van 2. Range location for Van 1 varied from 570 ft to 519 ft and Van 2 varied from 563 ft to 569 ft.

No problems occurred on this day.

Day: 329

Rating: Good

On 11-25-74, testing occurred between the hours of 13:56 and 16:52 for a total testing of 2:54. Total number of runs for the day were 55 with both van(s) operating. Excellent run(s) of the day was run 12.

Aircraft included:	B-707-19	B-727-8
	B-737-1	B-747-13
	DC-8-5	DC-9-3
	DC-10-2	L-1011-2
	VC-10-1	BAC111-0

and 1 miscellaneous aircraft. Wind conditions varied between 10 and 18 knots over 330° to 350°. Signal to noise measurement was 55 to 52 for Van 1 and 52 to 56 for Van 2. Range location for Van 1 varied from 560 ft to 550 ft and Van 2 varied from 564 ft to 570 ft.

No problems occurred on this day.

Day: 337

Rating: Fair

On 12-3-74, testing occurred between the hours of 15:04 and 17:20 for a total testing time of 2:16. Total number of runs for the day were 54 with both van(s) operating. Excellent run(s) of the day were none.

Aircraft included:	B-707-19	B-727-9
	B-737-0	B-747-8
	DC-8-7	DC-9-6
	DC-10-2	L-1011-3
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 25 and 35 knots over 320° to 340°. Signal to noise measurement was 53 to 54 for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from N/A ft to 556 ft and Van 2 varied from N/A ft to 562 ft.

No problems occurred on this day.

Day: 339

Rating: Good

On 12-5-74, testing occurred between the hours of 12:31 and 12:39 for a total testing time of 0:8:13. Total number of runs for the day were 4 with both van(s) operating. Excellent run(s) of the day was run 4.

Aircraft included:	B-707-0	B-727-2
	B-737-0	B-747-0
	DC-8-0	DC-9-2
	DC-10-0	L-1011-0
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 6 and 8 knots over 030° to N/A°. Signal to noise measurement was 53 to N/A for Van 1 and 53 to N/A for Van 2. Range location for Van 1 varied from 564 ft to N/A ft and Van 2 varied from 562 ft to N/A ft.

No problems occurred on this day.

Day: 343

Rating: Good

On 12-9-74, testing occurred between the hours of 15:38 and 17:44 for a total testing time of 2:05. Total number of runs for the day were 52 with both van(s) operating. Excellent run(s) of the day were 49, 5.

Aircraft included:	B-707-15	B-727-11
	B-737-0	B-747-10
	DC-8-8	DC-9-3
	DC-10-3	L-1011-0
	VC-10-0	BAC111-2

and 0 miscellaneous aircraft. Wind conditions varied between 15 and 20 knots over 280° to 280°. Signal to noise measurement was N/A to N/A for Van 1 and 48 to N/A for Van 2. Range location for Van 1 varied from 555 ft to 532 ft and Van 2 varied from 560 ft to N/A ft.

Problem: Van 2 lost last 7 runs due to laser multimoding.

Problems occurring on other than test days:

289-10/16/74 — Problems occurred again with both processor and the 40dB C-cor amplifier were replaced with Avantek units.

293-10/20/74 — Problems have occurred in interfacing the aircraft I. D. Box and trouble shooting had begun on the problem.

309-11/5/74 — There was a problem with V_{pk} and V_{max} as recorded by the computer. Trouble shooting the system uncovered two wiring errors in the interface which had caused the dropping of a bit in V_{pk} and a change in scaling of V_{max}. These problems have been corrected.

328-11/24/74 — The computer was found to have a bad card which caused an intermittent interrupt. This card was replaced and the computer is functioning normally.

344-12/10/74 — A bad chip was found in the LDV "1" processor which resulted in the loss of the third bit of data. This chip was replaced.

Day: 079

Rating: Very Good

On 3-20-75, testing occurred between the hours of 11:07 and 18:03 for a total testing time of 6:55. Total number of runs for the day were 91 with both van(s) operating. Excellent run(s) of the day were 3, 6, 20, 25, 32, 42, and 43.

Aircraft included:	B-707-25	B-727-19
	B-737-0	B-747-17
	DC-8-13	DC-9-8
	DC-10-6	L-1011-1
	VC-10-1	BAC111-1

and 0 miscellaneous aircraft. Wind conditions varied between 20 and 30 knots over 290° to 330°. Signal to noise measurement was 54 to 55 for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 559 ft to 541 ft and Van 2 varied from 555 to 568 ft.

Problem: Lost the computer storage display scope for the whole day of testing.

Day: 080

Rating: Excellent

On 3-21-75, testing occurred between the hours of 13:16 and 15:56 for a total testing time of 2:39. Total number of runs for the day were 44 with both van(s) operating. Excellent run(s) of the day were 1, 4, 8, 9, 12, 13, 14, 16, 18, 19, 21, 23, 25, 27, 28, 30, 31, 34, 35, 36, 37, 41, 42, and 44.

Aircraft included:	B-707-13	B-727-8
	B-737-1	B-747-8
	DC-8-7	DC-9-4
	DC-10-2	L-1011-1
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 10 and 15 knots over 280° to 330°. Signal to noise measurement was 54 to 55 for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 558 ft to 580 ft and Van 2 varied from 561 ft to 568 ft.

Problem: Van 2 was down for the first run due to laser alignment.

Day: 085

Rating: Very Good

On 3-26-75, testing occurred between the hours of 8:46 and 11:16 for a total testing time of 2:29. Total number of runs for the day were 24 with both van(s) operating. Excellent run(s) of the day were 6, 7, 8, 9, 13, and 15.

Aircraft included:	B-707-9	B-727-5
	B-737-0	B-747-1
	DC-8-4	DC-9-4
	DC-10-1	L-1011-0
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 16 and 25 knots over 280° to 320°. Signal to noise measurement was 55 to 56 for Van 1 and 54 to 58 for Van 2. Range location for Van 1 varied from 561 ft to 609 ft and Van 2 varied from 559 ft to 548 ft.

Problem: Van 2 was down for run 23 due to laser power.

Day: 086

Rating: Very Good

On 3-27-75, testing occurred between the hours of 9:03 and 12:04 for a total testing time of 3:00. Total number of runs for the day were 23 with both van(s) operating. Excellent run(s) of the day were 5, 6, 7, 9, 10, 16, and 21.

Aircraft included:	B-707-10	B-727-5
	B-737-0	B-747-0
	DC-8-4	DC-9-3
	DC-10-1	L-1011-0
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 12 and 20 knots over 320° to 350°. Signal to noise measurement was 55 to 56 for Van 1 and 53 to 57 for Van 2. Range location for Van 1 varied from 563 ft to N/A ft and Van 2 varied from 569 ft to N/A ft.

Problem: Van 2 was down for run 2 and 3 due to laser alignment.

Day: 090

Rating: Very Good

On 3-31-75, testing occurred between the hours of 11:23 and 15:12 for a total testing time of 3:48. Total number of runs for the day were 62 with one van(s) operating. Excellent run(s) of the day were 19, 23, 44, 52, 55, and 62.

Aircraft included:	B-707-14	B-727-14
	B-737-0	B-747-15
	DC-8-4	DC-9-7
	DC-10-4	L-1011-3
	VC-10-1	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 12 and 30 knots over 310° to 340°. Signal to noise measurement was 53 to 57 for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 567 ft to 586 ft and Van 2 varied from N/A ft to N/A ft.

Problem: The scanner in Van 2 had problems believed caused by overheating. Chips No. 7421, 7473 and 7408 were replaced. Also the processor stopped for a short period of time due to overheating. Both line scans are not operational due to the loss of 3 and 4 relays.

Day: 094

Rating: Fair

On 4-4-75, testing occurred between the hours of 10:42 and 14:21 for a total testing time of 3:39. Total number of runs for the day were 32 with one van(s) operating. Excellent run(s) of the day were none.

Aircraft included:	B-707-5	B-727-11
	B-737-0	B-747-6
	DC-8-6	DC-9-3
	DC-10-1	L-1011-0
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 20 and 40 knots over 300° to 320°. Signal to noise measurement was 48 to 45 for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 556 ft to 629 ft and Van 2 varied from N/A ft to N/A ft.

Problems: One of the differential screws adjustment of the laser in Van 2 became to tight as to prohibit tuning the laser for maximum power. These pieces had galled under the stress imposed in routing laser alignment.

To remedy the situation, the front mount was disassembled, the bad threaded screw replaced and the threads were changed with appropriate dies and taps. After an initial attempt to align the laser the locking of another differential screw in the rear mount was discovered. The rear mount was partially disassembled, the threads on the binding screw chased and the same differential screw reinserted.

Day: 098

Rating: Good

On 4-8-75, testing occurred between the hours of 12:52 and 16:49 for a total testing time of 3:52. Total number of runs for the day were 72 with one van(s) operating. Excellent run(s) of the day was run 38.

Aircraft included:	B-707-20	B-727-20
	B-737-0	B-747-12
	DC-8-4	DC-9-6
	DC-10-2	L-1011-0
	VC-10-2	BAC111-5

and 1 miscellaneous aircraft. Wind conditions varied between 13 and 20 knots over 310° to 340°. Signal to noise measurement was N/A to N/A for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 557 ft to 611 ft and Van 2 varied from N/A ft to N/A ft.

Problem: Continuing repairs on differential screws on the laser.

Day: 099

Rating: Fair

On 4-9-75, testing occurred between the hours of 14:50 and 15:20 for a total testing time of 0:24:14. Total number of runs for the day were 10 with one van(s) operating. Excellent run(s) of the day were none.

Aircraft included:	B-707-3	B-727-0
	B-737-1	B-747-2
	DC-8-2	DC-9-1
	DC-10-0	L-1011-0
	VC-10-1	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 14 and 16 knots over 310° to 340°. Signal to noise measurement was 54 to 55 for Van 1 and 52 to N/A for Van 2. Range Location for Van 1 varied from 569 ft to 572 ft and Van 2 varied from N/A ft to N/A ft.

Problem: Continuing repairs on differential screws on the laser.

Day: 111

Rating: Fair

On 4-21-75, testing occurred between the hours of 17:22 and 18:27 for a total testing time of 1:04. Total number of runs for the day were 11 with both van(s) operating. Excellent run(s) of the day were none.

Aircraft included:	B-707-3	B-727-5
	B-737-0	B-747-1
	DC-8-2	DC-9-0
	DC-10-0	L-1011-0
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 25 and 25 knots over 320° to 320°. Signal to noise measurement was 53 to 60 for Van 1 and 49 to 53 for Van 2. Range location for Van 1 varied from N/A ft to N/A ft and Van 2 varied from N/A ft to N/A ft.

Problem: No problems occurred on this day.

Day: 115

Rating: Very Good

On 4-25-74, testing occurred between the hours of 10:53 and 14:11 for a total testing time of 3:18. Total number of runs for the day were 34 with both van(s) operating. Excellent run(s) of the day were 16, 26, 27, 30, 33, 35, 36, and 38.

Aircraft included:	B-707-3	B-727-11
	B-737-0	B-747-3
	DC-8-5	DC-9-8
	DC-10-1	L-1011-1
	VC-10-0	BAC111-3

and 0 miscellaneous aircraft. Wind conditions varied between 2 and 2 knots over 230° to 350°. Signal to noise measurement was N/A to N/A for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 556 ft to 591 ft and Van 2 varied from 561 ft to 579 ft.

Problem: Computer for 1 and 2 had a false fly-by due to a noise spike from the computer interface.

Day: 118

Rating: Very Good

On 4-28-75, testing occurred between the hours of 13:57 and 15:20 for a total testing time of 1:22. Total number of runs for the day were 26 with both van(s) operating. Excellent run(s) of the day were 3, 8, 11, 13, and 21.

Aircraft included:	B-707-5	B-727-6
	B-737-1	B-747-5
	DC-8-1	DC-9-3
	DC-10-1	L-1011-0
	VC-10-1	BAC111-3

and 0 miscellaneous aircraft. Wind conditions varied between 6 and 14 knots over 230° to 280°. Signal to noise measurement was 51 to 54 for Van 1 and 50 to 51 for Van 2. Range location for Van 1 varied from 568 ft to 587 ft and Van 2 varied from 573 ft to 574 ft.

Probelm: No problem occurred on this day.

Day: 126

Rating: Fair

On 5-6-75, testing occurred between the hours of 11:23 and 12:12 for a total testing time of 0:49:21. Total number of runs for the day were 9 with both van(s) operating. Excellent run(s) of the day were none.

Aircraft included:	B-707-3	B-727-2
	B-737-0	B-747-0
	DC-8-4	DC-9-0
	DC-10-0	L-1011-0
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 8 and 10 knots over 210° to 210°. Signal to noise measurement was N/A to 54 for Van 1 and 53 to 54 for Van 2. Range location for Van 1 varied from 567 ft to N/A ft and Van 2 varied from 563 ft to N/A ft.

Problem: No problems occurred on this day.

Day: 127

Rating: Good

On 5-7-75, testing occurred between the hours of 11:37 and 16:33 for a total testing time of 4:56. Total number of runs for the day were 56 with one van(s) operating. Excellent run(s) of the day was run 4.

Aircraft included:	B-707-13	B-727-10
	B-737-1	B-747-12
	DC-8-7	DC-9-6
	DC-10-4	L-1011-1
	VC-10-1	BAC111-1

and 0 miscellaneous aircraft. Wind conditions varied between 5 and 12 knots over 280° to 350°. Signal to noise measurement was N/A to N/A for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 556 ft to 559 ft and Van 2 varied from N/A ft to N/A ft.

Problem: Running test on the translator in Van 2.

Day: 136

Rating: Excellent

On 5-16-75, testing occurred between the hours of 11:46 and 17:37 for a total testing time of 5:51. Total number of runs for the day were 77 with one van(s) operating. Excellent run(s) of the day were 4, 22, 32, 34, 43, 46, 48, 49, 51, 56, 57, 58, 68, and 70.

Aircraft included:	B-707-15	B-727-18
	B-737-1	B-747-15
	DC-8-12	DC-9-5
	DC-10-5	L-1011-3
	VC-10-2	BAC111-1

and 0 miscellaneous aircraft. Wind conditions varied between 3 and 15 knots over 220° to 360°. Signal to noise measurement was 55 to 57 for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 599 ft to N/A ft and Van 2 varied from N/A ft to N/A ft.

Problem: Running test on the translator in Van 2.

Day: 140

Rating: Very Good

On 5-20-75, testing occurred between the hours of 09:58 and 12:22 for a total testing time of 2:24. Total number of runs for the day were 20 with one van(s) operating. Excellent run(s) of the day were 2, 3, 4, and 11.

Aircraft included:	B-707-5	B-727-6
	B-737-0	B-747-1
	DC-8-5	DC-9-2
	DC-10-0	L-1011-1
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 5 and 10 knots over 210° to 230°. Signal to noise measurement was N/A to N/A for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 559 ft to N/A ft and Van 2 varied from N/A ft to N/A ft.

Problem: Running test on the translator in Van 2.

Day: 141

Rating: Very Good

On 5-21-75, testing occurred between the hours of 10:07 and 11:59 for a total testing time of 1:52. Total number of runs for the day were 16 with one van(s) operating. Excellent run(s) of the day were 10, 11, 12, 13, and 18.

Aircraft included:	B-707-2	B-727-5
	B-737-0	B-747-1
	DC-8-5	DC-9-2
	DC-10-0	L-1011-1
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 8 and 10 knots over 230° to 240°. Signal to noise measurement was N/A to N/A for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 552 ft to N/A ft and Van 2 varied from N/A ft to N/A ft.

Problem: Running test on the translator in Van 2.

Day: 147

Rating: Good

On 5-27-75, testing occurred between the hours of 10:54 and 15:00 for a total testing time of 4:06. Total number of runs for the day were 37 with one van(s) operating. Excellent run(s) of the day was run 24.

Aircraft included:	B-707-9	B-727-10
	B-737-0	B-747-6
	DC-8-7	DC-9-4
	DC-10-0	L-1011-1
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 12 and 16 knots over 230° to 290°. Signal to noise measurement was N/A to N/A for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 556 ft to N/A ft and Van 2 varied from N/A ft to N/A ft.

Problem: Van 2 was down due to a bad laser power supply.

Day: 148

Rating: Good

On 5-28-75, testing occurred between the hours of 10:24 and 16:07 for a total testing time of 5:43. Total number of runs for the day were 57 with one van(s) operating. Excellent run(s) of the day were 32, 35, and 36.

Aircraft included:	B-707-16	B-727-15
	B-737-0	B-747-12
	DC-8-8	DC-9-3
	DC-10-2	L-1011-1
	VC-10-0	BAC111-0

and 0 miscellaneous aircraft. Wind conditions varied between 10 and 12 knots over 240° to 36°. Signal to noise measurement was N/A to N/A for Van 1 and N/A to N/A for Van 2. Range location for Van 1 varied from 557 ft to 614 ft and Van 2 varied from N/A ft to N/A ft.

Problems: Van 2 is still down due to a laser power supply.

Appendix B
CROSS REFERENCE

Appendix B

The following pages present a cross compilation of data recorded at KIA according to aircraft type. For each aircraft, wind speed and direction are are presented for each van involving the specified aircraft type. Aircraft types are listed in the following order:

B-707
B-727
B-737
B-747
DC-8
DC-9
DC-10
L-1011
BAC-111
VC-10
Misc.

Table B-1 lists all data runs by day, run number, wind direction and wind speed. Table B-2 lists data runs by day and run number with three sections for winds less than 10 knots, 10 to 20 knots and greater than 20 knots.

Table B-1

B-707

Day	Run	Wind Speed (knots)	Wind Direction (deg)
266	3	Not Recorded	Not Recorded
266	8		
266	12		
266	13		
266	15		
266	17		
266	31		
266	33		
266	34		
266	37		
266	42		
266	48		
266	49		
266	51		
266	52		
270	7		
270	9		
270	14		
270	17		
270	20		
270	27		
270	30		
270	32		
270	34		
273	8		
275-1	2		
275-1	13		
275-2	4		
275-2	7		
275-2	11		
275-2	15		
275-2	17		
275-2	23		
275-2	26		
275-2	28		
275-2	30		
276	5		
276	11		
276	12		
276	13		
276	14		
276	15		
276	16		
276	24		
276	25		
276	27		
276	28		
276	31		
276	33		
277	1		
277	9		
277	21		
277	22	Not Recorded	Not Recorded
282	1	7	280
282	2	7	280
282	4	7	280
282	9	4	360
282	13	7	240
282	18	7	210
283	13	15	280
283	16	15	280
283	21	15	310
283	24	14	280
288	6	12	250
288	10	10	230
288	13	8	250
288	14	10	250
288	17	12	250
288	20	10	250

Day	Run	Wind Speed (knots)	Wind Direction (deg)
288	25	14	240
288	28	12	250
288	31	15	250
288	39	10	250
288	41	12	290
288	42	15	280
288	51	13	330
288	51	13	360
288	55	14	340
288	56	14	340
288	58	10	350
288	60	15	360
288	66	14	360
288	70	15	350
288	71	14	350
288	72	12	340
288	74	15	260
288	76	10	360
288	85	12	350
288	90	10	350
288	94	10	340
288	96	10	340
288	98	10	340
288	103	10	360
288	104	6	360
288	106	8	320
288	108	8	320
288	83	10	350
288	111	8	320
288	112	8	320
288	114	8	320
290	4	12	240
290	5	12	240
290	8	11	230
290	11	10	250
290	16	10	250
290	19	15	250
290	22	10	250
290	28	14	240
290	32	10	230
294	12	12	350
294	16	10	340
294	19	12	350
294	24	17	310
294	26	15	330
294	36	15	340
294	44	19	330
294	45	19	330
294	47	13	310
294	48	14	330
294	53	14	330
294	54	14	330
294	55	14	330
294	56	14	330
294	65	12	310
294	66	12	310
294	68	16	340
394	69	16	340
294	71	16	320
294	73	16	320
294	79	12	340
296	4	10	290
296	7	10	280
296	10	10	280
296	11	9	290
296	14	9	320
296	18	13	310
294	19	14	330
296	20	12	290
296	22	12	300

B-707

Day	Run	Wind Speed (knot)	Wind Direction (deg)
296	28	15	330
296	31	15	290
296	34	15	310
296	40	15	330
296	45	15	330
296	46	12	330
296	51	12	310
310	2	5	220
310	3	5	220
310	5	4	210
310	14	3	220
310	22	3	220
310	29	3	220
310	30	2	180
310	36	2	210
310	37	2	210
310	40	2	210
319	1	20	280
319	5	20	280
319	19	18-28	280
319	22	20	270
319	26	20	280
319	27	20-27	280
319	29	25	280
319	37	20	270
319	38	20	270
319	39	20-30	280
319	40	20-30	280
319	41	20-30	280
319	50	20-30	280
319	54	20-30	270
319	59	20	280
319	62	20-30	270
319	67	20	270
319	68	23	280
319	71	23	280
319	78	20	280
319	81	18-25	280
319	82	18-25	280
322	5	14	230
322	6	14	230
322	12	13	240
322	13	13	240
322	14	13	240
322	15	13	240
322	17	14	260
326	3	20	340
326	5	20	340
326	10	15	340
326	13	18	360
326	14	20	340
326	18	18	340
326	24	20	340
326	32	15	330
326	37	15	330
326	41	18	330
326	43	17	330
326	46	12	330
326	50	15	330
326	53	12	340
326	56	15	340
329	3	15	340
329	4	15	350
329	9	15	350
329	13	14	340
329	23	15	330
329	24	15	340
329	25	18	340
329	34	15	330
329	35	15	330
329	36	18	340
329	37	15	320
329	40	15	330
329	41	15	330
329	42	15	330
329	43	10	330
329	49	15	330
329	53	12	340
329	55	12	340
329	56	12	340
337	1	30	320
337	4	30	320
337	5	30	330
337	6	30	330
337	8	30	330
337	10	30	330
337	11	30	330
337	12	30-35	330
337	18	30	330
337	20	25-35	330
337	25	25-35	320
337	27	25-35	320
337	28	25-35	320
337	32	25-35	320
337	38	25-35	320
337	39	25-35	320
337	47	25-35	340
337	51	20-35	340
337	52	25-35	330
343	3	15	280
343	7	20	280
343	8	20	280
343	12	18	280
343	22	20	280
343	26	15	280
343	28	18	280
343	31	18	280
343	32	18	280
343	37	20	280
343	40	20	280
343	42	20	280
325	5	30-36	270
325	6	25-36	270
325	7	26-36	270
325	10	24	270
325	18	25-35	270
325	19	25-35	270
325	27	30	270
325	29	25-35	250
325	32	30-40	250
079	2	20	290
079	3	20	290
079	13	25	300
079	18	20	300
079	20	25	320
079	23	20	310
079	24	26	300
079	25	27	310
079	27	25	300
079	34	22	310
079	38	25	310
079	40	26	300
079	41	20	310
079	43	25	320
079	45	25	320
079	47	25	320
079	52	25	300
079	75	20-30	320
079	76	20-30	320
079	79	24	330
079	80	24	330
079	83	25	330

B-707

Day	Run	Wind Speed (knot)	Wind Direction (deg)	Day	Run	Wind Speed (knot)	Wind Direction (deg)
079	85	25	330	098	67	10	330
079	88	35-40	320	098	68	15	330
079	12	27	310	098	69	15	330
				098	71	20	340
080	1	10	290				
080	4	10	310	099	4	16	310
080	6	10	290	099	5	16	310
080	16	14	290	099	8	14	340
080	18	14	320				
080	26	15	290	111	1	25	320
080	27	13	310	111	3	25	320
080	28	13	310	111	5	25	320
080	30	15	310				
080	32	14	330	115	22	2	350
080	33	14	330	115	27	2	340
080	36	10	300	115	33	2	230
080	44	13	280				
				118	8	6	250
085	3	16	290	118	13	12	280
085	5	17	280	118	23	14	270
085	7	25	320	118	24	10	270
085	8	25	320	118	25	10	230
085	9	20	320				
085	10	18	320	126	6	10	210
085	11	18	320	126	9	9	210
085	12	18	320	126	10	8	210
085	13	17	320				
				127	2	5	340
086	4	20	340	127	5	5	340
086	6	18	330	127	7	5	340
086	7	12	340	127	8	6	280
086	9	20	350	127	11	5	350
086	10	20	320	127	21	10	340
086	11	17	340	127	23	12	350
086	15	20	330	127	36	10	350
086	16	14	330	127	38	8	340
086	17	15	330	127	39	8	340
086	24	18	330	127	40	8	340
				127	45	9	280
090	11	15-25	310	127	46	9	280
090	26	20-30	280				
090	28	20	280	136	10	8	360
090	33	20	310	136	12	12	340
090	34	20	310	136	19	12	330
090	37	15	340	136	25	8	360
090	39	20-30	300	136	26	8	360
090	43	25	280	136	37	8	360
090	44	12-20	280	136	41	5	350
090	49	18	280	136	52	15	330
090	56	18	280	136	55	15	330
090	57	18	280	136	59	5	340
090	60	18	280	136	62	8	340
090	61	18	280	136	64	4	280
				136	72	3	270
094	7	20-30	320	136	75	8	220
094	8	25-35	320	136	76	6	220
094	20	30-40	300				
094	25	35	310	140	9	5	220
094	29	30	310	140	10	10	230
				140	19	7	210
098	10	20	330	140	20	8	210
098	13	20	340	140	21	10	210
098	16	20	340				
098	19	20	340	141	7	10	240
098	25	15	340	141	11	8	230
098	30	10	340				
098	39	13	340	147	3	12	270
098	42	13	340	147	13	14	290
098	49	16	320	147	14	16	280
098	52	16	340	147	16	16	280
098	53	20	340	147	20	14	280
098	55	16	340	147	32	12	280
098	56	16	340	147	34	15	280
098	61	13	310	147	36	14	250
098	65	10	330	147	37	14	250
098	66	10	330				
				148	3	14	250
				148	4	12	320

B-707

Day	Run	Wind Speed (knots)	Wind Direction (deg)	Day	Run	Wind Speed (knots)	Wind Direction (deg)
148	9	12	320				
148	12	12	320				
148	15	12	340				
148	16	12	360				
148	17	12	360				
148	32	10	330				
148	33	10	330				
148	34	10	330				
148	35	10	330				
148	43	10	240				
148	46	12	240				
148	47	10	230				
148	51	10	240				
148	55	12	240				

B-727

Day	Run	Wind Speed (knots)	Wind Direction (deg)
266	6	Not Recorded	Not Recorded
266	16		
266	29		
266	30		
266	33		
266	38		
266	39		
266	47		
266	53		
270	11		
270	13		
270	21		
270	35		
273	3		
273	4		
275-1	1		
275-1	8		
275-1	10		
275-1	14		
275-2	2		
275-2	14		
275-2	16		
275-2	20		
275-2	22		
275-2	27		
276	7		
276	26		
276	29		
277	6		
277	8		
277	11		
277	14	Not Recorded	Not Recorded
282	7	5	310
282	8	5	310
282	12	7	240
282	14	7	260
282	15	7	260
283	1	5	310
283	2	5	310
283	19	15	310
283	25	14	280
288	1	9	250
288	3	9	250
288	8	10	250
288	11	7	250
288	12	8	240
288	18	14	250
288	21	10	250
288	24	12	250
288	30	15	250
288	34	14	240
288	38	10	250
288	44	13	330
288	47	13	330
288	61	15	350
288	64	12	350
288	69	12	340
288	84	10	340
288	92	10	320
288	109	8	320
288	117	8	320
288	118	8	320
290	9	12	240
290	15	15	250
294	6	12	360
294	7	12	360
294	9	10	350
294	33	15	340
294	37	15	350
294	41	15	340
294	42	19	330
294	56	14	330
294	70	16	340
294	75	15	330
294	80	12	340
296	5	13	330
296	12	10	280
296	32	15	290
310	10	Calm	Calm
310	20	3	220
310	23	3	220
310	33	2	40
310	41	4	60
319	4	20	280
319	6	20	280
319	7	20	280
319	32	20	280
319	33	25	270
319	42	20-30	290
319	47	20-30	270
319	58	20-30	280
319	63	20-30	270
319	69	23	280
319	70	23	280
319	77	20	280
319	79	20	280
322	10	13	240
323	1	4	220
323	3	2	260
325	1	25-35	270
325	3	20-36	270
325	4	25-37	270
325	8	25-36	270
325	9	28-38	270
325	12	25-35	260
325	13	30	260
325	17	25-35	260
325	22	30	250
325	24	30	270
325	25	30	270
325	37	32-40	250
325	38	32-40	270
325	39	25-35	270
326	4	24	340
326	7	15-25	340
326	19	20	340
326	20	20	340
326	25	20-25	340
326	47	13	330
326	48	13	330
326	51	15	330
326	53	12	340
326	58	15	340
326	63	15	320
329	2	18	340
329	5	15	350
329	7	18	350
329	28	15	320
329	29	14	340
329	30	14	340
329	51	14	340
329	58	12	320
337	13	30-35	330
337	16	30-35	330
337	19	25	330

B-727

Day	Run	Wind Speed (knots)	Wind Direction (deg)	Day	Run	Wind Speed (knots)	Wind Direction (deg)
337	22	25	320	094	3	30	340
337	31	25-35	320	094	5	20-30	320
337	37	25-35	320	094	6	30-40	330
337	48	25-35	340	094	11	30	320
337	52	25-35	330	094	15	30-40	320
337	53	25-35	330	094	17	30-40	310
339	2	6	030	094	19	30-45	320
339	3	6	030	094	26	30-40	320
343	1	16	280	094	30	30	310
343	10	15	280	094	31	35	330
343	11	20	280	094	32	35	330
343	16	17	280	098	5	20	350
343	20	20	280	098	6	20	350
343	24	20	280	098	7	18	340
343	41	20	280	098	11	20	340
343	42	20	280	098	14	20	340
343	46	20	280	098	18	20	340
079	1	20	290	098	22	15	340
079	7	20-30	310	098	23	12	340
079	10	20-30	310	098	24	12	340
079	16	20	320	098	28	15	340
079	17	15-25	310	098	32	16	330
079	21	20	300	098	33	15	340
079	22	20	310	098	35	13	340
079	29	25	310	098	44	13	340
079	31	25	310	098	45	16	320
079	33	20	310	098	47	16	320
079	54	25	320	098	58	15	330
079	56	25	330	098	59	15	330
079	65	25-30	320	098	72	20	340
079	73	20-30	320	098	73	20	340
079	81	25	330	111	4	25	320
079	82	25	330	111	7	25	310
079	84	25	330	111	8	25	310
079	89	35-40	320	111	9	25	310
079	91	35-40	320	111	10	25	310
080	5	10	330	115	5	6	360
080	9	15	290	115	6	6	360
080	11	10	310	115	7	6	360
080	15	15	330	115	12	5	310
080	17	14	320	115	21	7	360
080	19	15	290	115	24	4	340
080	37	15	330	115	29	2	340
080	39	15	330	115	32	3	290
085	1	20	280	115	34	2	230
085	4	17	280	115	36	10	220
085	14	20	320	115	39	10	220
085	17	19	320	118	2	10	290
085	22	25	300	118	4	14	290
086	8	12	340	118	6	11	330
086	12	20	340	118	14	12	280
086	13	25	350	118	18	13	280
086	19	20	320	126	7	10	210
086	20	12	340	126	13	10	210
090	1	15-25	310	127	3	5	340
090	5	15-25	310	127	12	10	330
090	7	22	300	127	15	10	330
090	9	20-25	280	127	17	14	340
090	10	20-25	280	127	18	13	340
090	14	15-25	280	127	22	10	340
090	15	15-25	310	127	30	8	320
090	20	15-20	310	127	33	8	360
090	24	20-30	280	127	41	8	340
090	30	10	320	127	48	12	310
090	35	15	310	136	3	5	300
090	38	20-30	300	136	6	8	280
090	42	25	280	136	9	8	340
090	59	20	290	136	13	10	360

B-727

Day	Run	Wind Speed (knots)	Wind Direction (deg)	Day	Run	Wind Speed (knots)	Wind Direction (deg)
136	15	10	360				
136	18	12	330				
136	27	8	360				
136	28	8	360				
136	30	10	350				
136	33	8	350				
136	38	8	360				
136	42	8	350				
136	45	8	350				
136	46	8	350				
136	47	5	340				
136	56	8	320				
136	67	10	290				
136	68	10	290				
140	5	7	200				
140	8	7	230				
140	12	10	220				
140	13	8	220				
140	14	8	200				
140	18	10	190				
141	4	12	240				
141	10	7	250				
141	13	8	240				
141	16	8	240				
141	17	6	230				
147	2	12	270				
147	4	12	270				
147	5	12	270				
147	8	12	270				
147	12	15	280				
147	22	14	280				
147	25	12	280				
147	26	12	280				
147	29	13	290				
147	35	14	250				
148	5	12	320				
148	6	12	320				
148	7	12	320				
148	10	12	320				
148	21	8	300				
148	24	8	350				
148	26	10	320				
148	27	10	320				
148	29	10	320				
148	31	10	330				
148	38	10	270				
148	39	10	260				
148	54	12	240				
148	57	12	240				

B-737

Day	Run	Wind Speed (knots)	Wind Direction (deg)	Day	Run	Wind Speed (knots)	Wind Direction (deg)
276	20	10	250				
290	33	10	350				
294	30	10	350				
296	43	13	340				
310	42	2	60				
322	11	13	240				
329	27	15	340				
080	38	15	310				
099	10	13	340				
118	27	6	250				
127	32	8	330				
136	61	10	340				

B-747

Day	Run	Wind Speed (knots)	Wind Direction (deg)
266	2	Not Recorded	Not Recorded
266	7	↓	↓
266	9		
266	11		
266	22		
266	24		
266	25		
266	27		
266	28		
266	36		
266	40		
266	44		
266	45		
273	1		
273	5		
273	7		
275-1	11		
275-2	3		
275-2	6		
275-2	19		
276	1		
276	9		
276	17		
276	23		
276	30		
276	34		
276	37		
277	3		
277	5		
277	15		
277	20		
277	23	Not Recorded	Not Recorded
282	5	7	280
282	6	7	330
282	16	4	230
282	17	10	220
283	4	15	280
283	5	15	280
283	7	15	280
283	8	15	280
283	11	15	280
283	12	15	280
283	14	15	280
283	15	15	280
283	17	15	280
283	18	15	280
283	23	14	280
288	23	12	250
288	33	15	250
288	43	15	280
288	45	13	330
288	49	12	340
288	52	13	360
288	57	10	350
288	67	15	340
288	73	12	360
288	78	14	350
288	79	14	350
288	81	10	350
288	86	12	350
288	87	10	340
288	88	10	350
288	93	10	340
288	101	10	320
288	102	10	340
288	107	8	320
288	115	8	320

Day	Run	Wind Speed (knots)	Wind Direction (deg)
290	12	10	250
290	14	10	230
290	20	12	240
290	23	14	250
290	24	15	260
290	27	14	240
290	30	13	230
294	4	14	340
294	8	12	360
294	10	10	340
294	13	10	340
294	18	12	350
294	23	15	340
294	27	13	330
294	28	15	340
294	32	15	350
294	35	15	340
294	38	13	340
294	39	13	340
294	40	15	340
294	46	13	310
294	49	14	330
294	52	14	330
294	59	12	310
294	60	12	310
294	63	12	310
294	76	15	330
294	78	15	330
296	13	12	310
296	15	10	320
296	16	10	330
296	23	15	310
296	25	15-20	320
296	29	10	300
296	30	10	300
296	33	15	310
296	38	15	310
296	42	15	320
296	47	15	330
296	49	10	330
296	53	10	340
310	4	4	210
310	6	5	200
310	16	3	220
310	27	2	180
310	28	3	220
319	8	20	280
319	10	20	280
319	12	20-25	290
319	13	20-35	290
319	15	22	280
319	17	22	280
319	19	18-28	280
319	24	20	280
319	25	20	280
319	31	20	280
319	46	20-30	270
319	48	20-30	270
319	51	20-30	270
319	52	20-30	270
319	58	20	280
319	60	20	280
319	61	20-30	270
319	66	20	270
319	73	20	270
319	74	20	270
322	4	14	230
322	9	14	230

B-747

Day	Run	Wind Speed (knots)	Wind Direction (deg)
322	16	14	260
325	20	25	270
325	26	30	270
325	28	25	270
325	33	30-40	250
325	35	30-35	240
325	36	30-38	250
325	42	25-35	260
326	16	20	350
326	21	18	340
326	22	18	340
326	26	18	340
326	28	20	340
326	31	15	330
326	35	18	340
326	38	16	330
326	39	16	330
326	42	17	330
326	60	15	340
326	64	15	330
329	8	15	350
329	15	15	340
329	16	15	340
329	18	20	320
329	19	20	330
329	22	15	340
329	31	14	340
329	38	15	340
329	46	15	330
329	48	18	340
329	52	14	340
329	54	12	340
329	57	12	340
337	15	30	330
337	21	25-35	330
337	30	25-35	320
337	41	25-35	330
337	45	25-35	330
337	46	25-35	330
337	49	20-35	340
337	57	25-35	340
343	13	18	280
343	17	17	280
343	19	18	280
343	27	17	280
343	30	17	280
343	33	18	280
343	38	20	280
343	39	20	280
343	44	20	280
343	45	20	280
079	30	25	310
079	32	20	310
079	35	22	310
079	39	20-30	330
079	42	20	310
079	44	25	320
079	46	25	320
079	49	25	320
079	50	25	320
079	55	25	330
079	60	20	320
079	61	25	320
079	62	25	320
079	66	25-30	320
079	67	25-30	320
079	71	20-30	320
079	77	24	330
080	2	10	290
080	12	14	290
080	23	10-15	290
080	24	10-15	290
080	25	12	280
080	29	15	310
080	35	10	330
080	41	13	330
085	15	20	320
090	12	15-25	310
090	16	15-30	280
090	17	15-25	280
090	22	20-30	280
090	25	20	280
090	27	20	280
090	31	20	310
090	36	15	310
090	40	20	280
090	45	12-20	280
090	48	18	280
090	54	12	280
090	55	15	280
090	58	25	280
090	62	15	290
094	4	30	310
094	10	25-35	320
094	22	30-40	300
094	27	35	320
094	28	35	320
094	34	35	330
098	4	20	350
098	8	18	340
098	17	20	340
098	20	20	340
098	38	13	340
098	40	13	340
098	43	13	340
098	46	16	320
098	48	14	340
098	57	15	330
098	60	15	290
098	70	20	340
099	3	14	310
099	7	14	340
111	6	25	320
115	19	5	320
115	25	4	340
115	38	10	220
118	1	8	290
118	11	6	280
118	15	12	320
118	19	14	280
118	21	10	270
127	10	8	350
127	16	10	330
127	20	10	340
127	26	8	330
127	29	15	330
127	34	15	340
127	35	10	350
127	37	10	340
127	43	10	350
127	44	12	310
127	47	9	280
127	53	7	340
136	5	5	250
136	17	8	360

B-747

Day	Run	Wind Speed (knots)	Wind Direction (deg)	Day	Run	Wind Speed (knots)	Wind Direction (deg)
136	20	10	340				
136	23	8	350				
136	32	8	350				
136	35	8	350				
136	36	8	350				
136	43	8	340				
136	44	8	340				
136	49	8	340				
136	50	5	340				
136	60	8	290				
136	66	8	290				
136	69	10	340				
136	74	10	230				
140	7	7	240				
141	12	8	240				
147	7	12	270				
147	15	16	290				
147	17	14	280				
147	19	14	280				
147	21	14	280				
147	38	14	250				
148	14	10	320				
148	19	10	310				
148	20	10	310				
148	23	8	350				
148	28	10	320				
148	30	10	320				
148	41	7	240				
148	42	7	240				
148	45	12	240				
148	49	10	240				
148	52	12	240				
148	53	12	240				

DC-8

Day	Run	Wind Speed (knots)	Wind Direction (deg)
266	4	Not Recorded	Not Recorded
266	14	↓	↓
266	20		
266	26		
266	43		
266	44		
266	50		
266	54		
270	4		
270	33		
273	6		
275-1	5		
275-1	9		
275-2	8		
275-2	9		
275-2	12		
275-2	21		
275-2	24		
275-2	25		
276	8		
276	10		
276	35		
277	2		
277	10		
277	17		
277	24		
277	25	Not Recorded	Not Recorded
282	10	5	330
282	19	7	230
283	9	15	280
283	22	14	280
283	26	14	280
288	2	9	250
288	7	10	250
288	19	14	250
288	22	10	250
288	30	12	250
288	40	15	290
288	53	13	340
288	65	12	350
288	68	15	340
288	75	10	360
288	77	14	350
288	82	10	350
288	89	10	350
288	99	10	320
288	100	10	320
288	105	10	360
288	110	8	320
288	113	8	320
290	2	11	230
290	3	10	230
290	6	14	230
290	10	14	250
290	13	8	250
290	25	15	250
290	26	12	250
294	1	14	340
294	2	14	340
294	5	12	360
294	17	12	350
294	21	12	350
294	25	12	310
294	29	11	360
294	43	19	330
294	50	14	330
294	64	12	310
294	67	12	310
294	74	16	330
294	77	15	330
296	2	10	310
296	3	8	330
296	6	12	330
296	9	10	290
296	17	11	290
296	21	16	330
296	35	10	310
296	41	15	330
296	50	10	320
310	8	4	210
310	9	4	210
310	11	4	210
310	12	4	210
310	13	3	220
310	15	2	220
310	17	2	220
310	18	2	22[illegible]
310	19	3	220
310	21	3	220
310	25	3	220
310	31	2	180
310	32	2	90
310	34	2	120
310	35	4	110
319	2	20	280
319	11	20	280
319	14	20-25	290
319	21	17	270
319	23	20	270
319	30	25	270
319	34	20	280
319	35	20-27	280
319	36	25	280
319	43	20-30	280
319	49	25	280
319	61	20-30	270
319	65	25	280
319	75	20	270
319	76	20	270
319	80	24	280
325	2	25-35	270
325	40	20-35	260
325	43	25-40	260
326	6	20	340
326	8	20	350
326	17	20	350
326	33	15	340
326	34	18	340
326	45	12	330
326	57	15	340
326	62	15	320
329	1	18	340
329	20	18	330
329	21	15	320
329	39	14	340
329	44	20	340
337	29	25-35	320
337	33	25-35	320
337	42	25-35	330
337	44	25-35	330
337	54	25-35	340
337	55	25-35	340
337	56	25-35	340

DC-8

Day	Run	Wind Speed (knots)	Wind Direction (deg)	Day	Run	Wind Speed (knots)	Wind Direction (deg)
343	4	18	280	127	4	5	340
343	6	20	280	127	6	5	340
343	18	18	280	127	19	10	360
343	29	15	280	127	49	7	310
343	36	20	280	127	50	7	350
343	48	18	290	127	52	7	340
343	49	15	280	127	54	7	340
343	50	15	280				
				136	2	5	320
079	4	20-30	290	136	7	6	360
079	9	20-30	310	136	16	10	360
079	15	30	310	136	24	12	310
079	26	25	300	136	31	10	360
079	36	20	320	136	39	8	350
079	68	20-30	320	136	40	8	350
079	69	20-30	320	136	48	5	340
079	70	20-30	320	136	51	10	280
079	74	20-30	320	136	63	4	280
079	78	24	330	136	71	4	220
079	86	35-30	330	136	78	5	220
079	87	35-40	330				
079	90	35-40	320	140	1	6	200
				140	6	7	240
080	7	14	330	140	15	10	210
080	13	14	290	140	16	10	210
080	14	15	300	140	17	10	210
080	20	10	290	141	3	15	250
080	22	10-15	290	141	8	10	240
080	34	10	300	141	14	10	240
080	40	15	300	141	15	10	240
				141	18	8	210
085	2	20	280				
085	16	20	320	147	6	12	270
085	18	25	290	147	9	12	270
085	19	25	290	147	10	15	280
				147	11	15	280
086	3	15	320	147	18	14	280
086	5	20	340	147	23	12	280
086	14	16	330	147	30	13	290
086	23	18	330				
				148	8	12	320
090	2	15-25	320	148	11	12	320
090	21	18	310	148	13	10	320
090	29	20	280	148	25	8	350
090	50	18	280	148	36	10	330
				148	44	10	240
094	9	25-35	320	148	50	10	240
094	14	30	320	148	56	14	240
094	18	32	310				
094	21	30-40	300				
094	24	30-40	320				
094	33	35	330				
098	29	10	340				
098	36	13	340				
098	64	10	330				
098	74	20	340				
099	1	15	330				
099	6	14	340				
111	2	25	320				
111	11	25	320				
115	8	6	360				
115	13	5	330				
115	16	7	340				
115	31	2	230				
115	35	2	230				
118	3	10	290				
126	8	10	210				
126	11	8	200				
126	12	10	210				
126	14	10	220				

DC-9

Day	Run	Wind Speed (knots)	Wind Direction (deg)
266	1	Not Recorded	Not Recorded
266	10	↓	↓
266	32		
270	5		
270	10		
270	12		
270	16		
270	31		
270	36		
273	2		
275-1	4		
275-1	12		
275-2	9		
276	3		
276	19		
276	21		
276	22		
276	35	↓	↓
277	4	Not Recorded	Not Recorded
282	3	7	280
288	4	12	250
288	5	12	250
288	9	10	230
288	15	10	250
288	16	12	250
288	26	14	240
288	27	15	240
288	32	15	250
288	37	15	250
288	46	13	330
288	50	12	340
288	63	12	350
288	80	12	350
288	95	10	340
290	1	10	230
290	7	14	250
290	17	10	250
290	21	13	240
294	3	14	340
294	14	10	340
294	15	10	340
294	31	15	350
294	34	15	340
294	58	14	330
296	24	15	310
296	27	15	310
296	44	15	340
296	48	10	330
310	38	2	90
310	39	2	60
319	3	20	280
319	10	20	280
319	28	20	280
319	45	20-30	270
319	56	20-30	280
322	8	14	230
323	2	4	220
325	11	30	270
325	14	28-36	260
325	15	28-36	260
325	21	30-40	260
325	30	30-40	250
325	31	30-38	250
325	41	20-36	260

Day	Run	Wind Speed (knots)	Wind Direction (deg)
326	2	20	340
326	9	20	350
326	12	15	340
326	23	15	340
326	40	18	330
326	52	12	340
329	10	15	340
329	26	10	330
329	47	18	330
337	2	25	310
337	7	30	330
337	26	25-35	320
337	35	25-35	320
337	36	25-35	320
339	1	6	030
339	4	8	030
343	2	17	280
343	21	15	280
343	23	20	280
079	8	20-30	310
079	11	20-30	310
079	14	20-25	310
079	19	15-25	300
079	28	25	310
079	48	25	320
079	57	25	320
079	72	20-30	320
080	3	10	310
080	10	10	310
080	31	14	300
080	43	13	280
085	6	17	280
085	21	25	300
085	23	26	340
085	34	20	330
086	2	15	320
086	21	15	340
086	22	22	320
090	3	15-25	310
090	4	15-25	310
090	6	22	300
090	8	20-25	280
090	13	15-25	280
090	41	20	280
090	53	12	280
094	12	30-40	330
094	16	30-40	310
094	35	35	330
098	9	20	330
098	15	20	340
098	27	15	340
098	41	13	340
098	50	15	360
098	62	10	290
099	9	13	340
115	9	6	360
115	10	10	350
115	11	11	340
115	14	7	340
115	17	9	320
115	18	9	320
115	20	7	360
115	28	2	340
118	9	6	250
118	20	10	280

DC-9

Day	Run	Wind Speed (knots)	Wind Direction (deg)	Day	Run	Wind Speed (knots)	Wind Direction (deg)
118	26	6	270				
127	13	10	330				
127	14	10	330				
127	24	12	350				
127	25	8	330				
127	42	8	340				
127	56	10	340				
136	8	8	340				
136	11	8	360				
136	14	10	360				
136	21	10	340				
136	57	8	320				
140	2	6	210				
140	4	7	200				
140	11	8	230				
141	2	12	240				
141	5	12	250				
147	27	12	280				
147	28	13	290				
147	31	12	280				
147	33	15	290				
148	2	12	320				
148	22	8	350				
148	37	10	270				

DC-10

Day	Run	Wind Speed (knots)	Wind Direction (deg)	Day	Run	Wind Speed (knots)	Wind Direction (deg)
266	19	Not Recorded	Not Recorded	136	58	8	310
266	23	↓	↓	136	73	6	240
				136	77	10	220
275-1	6						
275-1	7			148	18	10	310
275-2	1			148	40	10	260
275-2	5						
275-2	18						
276	6						
277	7						
277	12						
277	18						
277	19	Not Recorded	Not Recorded				
283	10	15	280				
288	59	14	350				
290	18	15	240				
294	20	12	350				
294	51	14	330				
296	26	15	310				
296	39	15	330				
296	52	12	310				
319	16	22	280				
319	55	20-30	270				
319	72	20	270				
326	27	18	340				
326	30	15	340				
326	44	15	330				
326	55	14	340				
326	61	15	320				
329	11	15	340				
329	45	15	320				
337	24	25-35	320				
337	43	20-35	330				
343	14	17	280				
343	15	15	280				
343	25	17	280				
079	6	20-30	290				
079	37	25	300				
079	53	25	320				
079	58	20	320				
079	59	20	320				
079	63	25	320				
080	8	10	290				
080	21	10-15	310				
085	20	15	290				
086	18	18	330				
090	18	15-25	280				
090	46	20	280				
090	47	20	280				
090	51	18	280				
094	13	25-35	320				
098	34	15	350				
098	63	10	290				
115	26	4	340				
118	17	13	280				
127	9	8	350				
127	27	15	330				
127	51	7	350				
127	55	10	340				
136	4	4	330				
136	53	15	330				

L-1011

Day	Run	Wind Speed (knots)	Wind Direction (deg)	Day	Run	Wind Speed (knots)	Wind Direction (deg)
266	18	Not Recorded	Not Recorded				
275-2	13	↓	↓				
276	4						
276	18						
277	16	Not Recorded	Not Recorded				
288	54	13	340				
288	97	10	340				
290	29	14	250				
294	22	15	340				
296	37	15	310				
310	1	5	220				
319	18	22	280				
319	53	20-30	270				
322	7	14	230				
326	36	12-20	340				
326	58	15	340				
329	14	15	340				
329	51	14	340				
337	9	25	330				
337	17	30	330				
337	40	25-35	320				
079	64	25	320				
080	42	13	280				
090	19	15-20	310				
090	32	20	310				
090	52	18	280				
127	31	8	330				
136	29	10	350				
136	65	8	290				
136	70	10	340				
141	9	10	240				
147	24	12	280				
148	48	10	240				

VC-10

Day	Run	Wind Speed (knots)	Wind Direction (deg)
270	29	Not Recorded	Not Recorded
276	32	↓	↓
283	6	15	280
288	91	10	340
290	31	8	240
294	72	16	320
326	29	20	340
329	12	14	340
079	51	25	300
090	23	18	280
098	31	16	330
098	51	15	360
099	2	15	330
118	16	12	300
127	28	15	330
136	22	8	360
136	34	8	350

BAC-111

Day	Run	Wind Speed (knots)	Wind Direction (deg)
325	34	30-38	250
343	5	20	280
343	9	19	280
079	5	20-30	290
098	3	20	350
098	12	20	340
098	21	15	340
098	26	15	340
098	37	13	340
115	23	2	350
115	30	2	340
115	37	10	220
118	5	11	330
118	7	11	330
118	22	10	270
136	1	5	340
140	3	3	190
141	6	12	240

MISC

	Day	Run	Wind Speed (knots)	Wind Direction (deg)
Four Eng. Prop.	266	21	Not Recorded	Not Recorded
Twin Eng. Prop.	266	41	↓	↓
Twin Eng.	270	6		
Twin Eng.	270	15		
Twin Eng. Prop.	270	18		
Twin Eng. Prop.	270	19		
Four Eng. Prop.	270	28		
Two Eng. Prop.	275-1	3		
Lear Jet	275-2	29	↓	↓
Lear Jet	276	2	Not Recorded	Not Recorded
C-880	288	116	8	320
C-880	296	36	15	310
Twin Eng. Jet	310	7	4	200
Lear Jet	310	24	3	220
2 Eng. Prop.	329	6	18	350
4 Eng. Prop.	098	54	16	340

Table B-2

B-707

< 10 knots		10-20 knots		> 20 knots	
Date	Run No..	Date	Run No.	Date	Run No.
282	1	283	13	319	19
282	2	283	16	319	27
282	4	283	21	319	29
282	9	283	24	319	39
282	13	288	6	319	40
282	18	288	10	319	41
288	13	288	14	319	50
288	104	288	17	319	54
288	106	288	20	319	62
288	108	288	25	319	68
288	111	288	28	319	71
288	112	288	31	319	81
288	114	288	39	319	82
296	11	288	41	325	5
296	14	288	42	325	6
310	2	288	48	325	7
310	3	288	51	325	10
310	5	288	55	325	18
310	14	288	56	325	19
310	22	288	58	325	27
310	29	288	60	325	29
310	30	288	66	325	32
310	36	288	70	337	1
310	37	288	71	337	4
310	40	288	72	337	5
		288	74	337	6
		288	76	337	8
		288	85	337	10
		288	90	337	11
		288	94	337	12
		288	96	337	18
		288	98	337	20
		288	103	337	25
		288	83	337	27
		290	4	337	28
		290	5	337	32
		290	8	337	38
		290	11	337	39
		290	16	337	47
		290	19	337	51
		290	22	337	52
		290	28		
		290	32		
		294	11		
		294	12		
		294	16		
		294	19		
		294	24		
		294	26		
		294	36		
		294	44		
		294	45		
		294	47		
		294	48		
		294	53		
		294	54		
		294	55		
		294	56		
		294	65		
		294	66		
		294	68		
		294	69		
		294	71		
		294	73		
		294	79		
		296	7		
		296	10		
		296	18		
		296	19		
		296	20		
		296	22		
		296	28		

B-707

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
		296	31		
		296	34		
		296	40		
		296	45		
		296	46		
		296	51		
		319	1		
		319	5		
		319	22		
		319	26		
		319	37		
		319	38		
		319	59		
		319	67		
		319	78		
		322	5		
		322	6		
		322	12		
		322	13		
		322	14		
		322	15		
		322	17		
		326	3		
		326	5		
		326	10		
		326	13		
		326	14		
		326	18		
		326	24		
		326	32		
		326	37		
		326	41		
		326	43		
		326	46		
		326	50		
		326	53		
		326	56		
		329	4		
		329	9		
		329	13		
		329	23		
		329	24		
		329	25		
		329	34		
		329	35		
		329	36		
		329	37		
		329	40		
		329	41		
		329	42		
		329	43		
		329	49		
		329	53		
		329	55		
		329	56		
		343	3		
		343	7		
		343	8		
		343	12		
		343	22		
		343	26		
		343	28		
		343	31		
		343	32		
		343	37		
		343	40		
		343	42		
	25		160		41

B-707

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
115	22	079	2	079	13
115	27	079	3	079	20
115	33	079	18	079	24
118	8	079	23	079	25
126	9	079	41	079	27
126	10	080	1	079	34
127	2	080	4	079	38
127	5	080	6	079	40
127	7	080	16	079	43
127	8	080	18	079	45
127	11	080	26	079	47
127	38	080	27	079	52
127	39	080	28	079	75
127	40	080	32	079	76
127	46	080	33	079	79
136	10	080	36	079	30
136	25	080	44	079	83
136	26	085	3	079	85
136	37	085	5	079	88
136	41	085	9	079	12
136	59	085	10	085	7
136	62	085	11	085	8
136	64	085	12	090	11
136	72	085	13	090	26
136	75	086	4	090	39
136	76	086	6	090	43
140	9	086	7	094	7
140	19	086	9	094	8
140	20	086	10	094	20
141	11	086	11	094	25
		086	15	094	29
		086	16	111	1
		086	17	111	3
		086	24	111	5
		090	28		
		090	33		
		090	34		
		090	37		
		090	44		
		090	49		
		090	56		
		090	57		
		090	60		
		090	61		
		098	10		
		098	13		
		098	16		
		098	19		
		098	25		
		098	30		
		098	39		
		098	42		
		098	49		
		098	52		
		098	53		
		098	55		
		098	56		
		098	61		
		098	65		
		098	66		
		098	67		
		098	68		
		098	69		
		098	71		
		099	4		
		099	5		
		099	8		
		118	13		
		118	23		
		118	24		

B-707

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
		118	25		
		126	6		
		127	21		
		127	23		
		127	36		
		136	12		
		136	19		
		136	52		
		136	55		
		140	10		
		140	21		
		141	7		
		147	3		
		147	13		
		147	14		
		147	16		
		147	20		
		147	32		
		147	34		
		147	36		
		147	37		
		148	3		
		148	4		
		148	9		
		148	12		
		148	15		
		148	16		
		148	17		
		148	32		
		148	33		
		148	34		
		148	35		
		148	43		
		148	46		
		148	47		
		148	51		
		148	55		
	31		107		34

B-727

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
282	7	283	19	319	33
282	8	283	25	319	42
282	12	288	8	319	47
282	14	288	18	319	58
282	15	288	21	319	63
283	1	288	24	319	69
283	2	288	30	319	70
288	1	288	34	325	1
288	3	288	38	325	3
288	11	288	44	325	4
288	12	288	47	325	8
288	117	288	61	325	9
288	118	288	64	325	12
310	10	288	69	325	13
310	20	288	84	325	17
310	23	288	92	325	22
310	33	290	9	325	24
310	41	290	15	325	25
323	1	294	6	325	27
323	3	294	7	325	37
339	2	294	9	325	38
		294	33	325	39
		294	37	326	4
		294	41	326	7
		294	42	326	25
		294	56	329	2
		294	70	329	7
		294	75	337	13
		294	80	337	16
		296	5	337	19
		296	12	337	22
		296	32	337	31
		319	4	337	37
		319	6	337	48
		319	7	337	52
		319	32	337	53
		319	77		
		319	79		
		322	10		
		326	19		
		326	20		
		326	47		
		326	48		
		326	51		
		326	53		
		326	58		
		326	63		
		329	5		
		329	28		
		329	29		
		329	30		
		329	51		
		329	58		
		343	1		
		343	10		
		343	11		
		343	16		
		343	20		
		343	24		
		343	41		
		343	42		
		343	46		
		343	53		
	22		63		36

B-727

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
115	5	079	1	079	7
115	6	079	16	079	10
115	7	079	21	079	17
115	12	079	22	079	29
115	21	079	33	079	31
115	24	080	5	079	54
115	29	080	9	079	56
115	32	080	11	079	65
115	34	080	15	079	73
118	12	080	17	079	81
127	3	080	19	079	82
127	30	080	37	079	84
127	33	080	39	079	80
127	41	085	1	079	91
136	3	085	4	085	22
136	6	085	14	086	13
136	9	085	17	090	1
136	27	086	8	090	5
136	28	086	12	090	7
136	33	086	19	090	9
136	38	086	20	090	10
136	42	090	20	090	14
136	45	090	30	090	15
136	46	090	35	090	24
136	47	090	59	090	38
136	56	098	5	090	42
140	5	098	6	094	3
140	8	098	7	094	5
140	13	098	11	094	6
140	14	098	14	094	11
141	10	098	18	094	15
141	13	098	22	094	17
141	16	098	23	094	19
141	17	098	24	094	26
148	21	098	28	094	30
148	24	098	32	094	31
		098	33	094	32
		098	35	111	4
		098	44	111	7
		098	45	111	8
		098	47	111	9
		098	58	111	10
		098	59		
		098	72		
		098	73		
		115	36		
		115	39		
		118	2		
		118	4		
		118	6		
		118	14		
		118	18		
		126	7		
		126	13		
		127	12		
		127	15		
		127	17		
		127	18		
		127	22		
		127	48		
		136	13		
		136	15		
		136	18		
		136	30		
		136	67		
		136	68		
		140	12		
		140	18		

B-727

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
		141	4		
		147	2		
		147	4		
		147	5		
		147	8		
		147	12		
		147	22		
		147	25		
		147	26		
		147	29		
		147	35		
		148	5		
		148	6		
		147	7		
		148	10		
		148	26		
		148	27		
		148	29		
		148	31		
		148	38		
		148	39		
		148	54		
		148	57		
		148	58		
	36		92		42

B-737

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
310	42	290	33		
		294	30		
		296	43		
		322	11		
		329	27		
	1		5		
118	27	080	38		
127	32	099	10		
		136	61		
	2		3		

B-747

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
282	5	282	17	296	25
282	6	283	4	319	12
282	16	283	5	319	13
		283	7	319	15
288	107	283	8	319	17
288	115	283	11	319	19
		283	12	319	46
310	4	283	14	319	48
310	6	283	15	319	51
310	16	283	17	319	52
310	27	283	18	319	61
310	28	283	23		
				325	20
		288	23	325	26
		288	33	325	28
		288	43	325	33
		288	45	325	35
		288	49	325	36
		288	52	325	42
		288	57		
		288	67	337	15
		288	73	337	21
		288	78	337	30
		288	79	337	41
		288	81	337	45
		288	86	337	46
		288	87	337	49
		288	88	337	57
		288	93		
		288	101		
		288	102		
		290	12		
		290	14		
		290	20		
		290	23		
		290	24		
		290	27		
		290	30		
		294	4		
		294	8		
		294	10		
		294	13		
		294	18		
		294	23		
		294	27		
		294	28		
		294	32		
		294	35		
		294	38		
		294	39		
		294	40		
		294	46		
		294	49		
		294	52		
		294	59		
		294	60		
		294	63		
		294	76		
		294	78		
		296	13		
		296	15		
		296	16		
		296	23		
		296	29		
		296	30		
		296	33		
		296	38		
		296	42		
		296	47		
		296	49		
		296	53		

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
		319	8		
		319	10		
		319	24		
		319	25		
		319	31		
		319	58		
		319	60		
		319	66		
		319	73		
		319	74		
		322	4		
		322	9		
		322	16		
		326	16		
		326	21		
		326	22		
		326	26		
		326	28		
		326	31		
		326	35		
		326	38		
		326	39		
		326	42		
		326	60		
		326	64		
		329	8		
		329	15		
		329	16		
		329	18		
		329	19		
		329	22		
		329	31		
		329	38		
		329	46		
		329	48		
		329	52		
		329	54		
		329	57		
		343	13		
		343	17		
		343	19		
		343	27		
		343	30		
		343	33		
		343	38		
		343	39		
		343	44		
		343	45		
	10		118		26
115	19			079	30
115	25	079	32	079	35
		079	42	079	39
118	1	079	60	079	44
118	11	080	2	079	46
127	10	080	12	079	49
127	26	080	23	079	50
127	47	080	24	079	55
127	53	080	25	079	61
136	5	080	29	079	62
136	17	080	35	079	66
136	23	080	41	079	67
136	32	085	15	079	71
136	35			079	77
136	36	090	25	090	12
136	43	090	27	090	16
136	44	090	31	090	17
136	49	090	36	090	22
136	50	090	40	090	58
136	60	090	45	094	4
136	66	090	48	094	10
		090	54	094	22
		090	55		
		090	62		

B-747

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
140	7	098	4	094	27
141	12	098	8	094	28
148	23	098	17	094	34
148	41	098	[illegible]	111	6
148	42	098	28		
		098	40		
		098	43		
		098	46		
		098	48		
		098	57		
		098	60		
		098	70		
		099	3		
		099	7		
		115	38		
		118	15		
		118	19		
		118	21		
		127	16		
		127	20		
		127	29		
		127	34		
		127	35		
		127	37		
		127	43		
		127	44		
		136	20		
		136	69		
		136	74		
		147	7		
		147	15		
		147	17		
		147	19		
		147	21		
		147	38		
		148	14		
		148	19		
		148	20		
		148	28		
		148	30		
		148	45		
		148	49		
		148	52		
		148	53		
	25		66		26

DC-8

< 10 knots		10-20 knots		> 20 knots	
Date	Run	Date	Run	Date	Run
282	10	283	9	319	14
282	19	283	22	319	30
288	2	283	26	319	35
288	110	288	7	319	36
288	113	288	19	319	43
290	13	288	22	319	49
296	3	288	30	319	61
310	8	288	40	319	65
310	9	288	53	337	29
310	11	288	65	337	33
310	12	288	68	337	42
310	13	288	75	337	44
310	15	288	77	337	54
310	17	288	82	337	55
310	18	288	89	337	56
310	19	288	99		
310	21	288	100		
210	25	288	105		
310	31	290	2		
310	32	290	3		
310	34	290	6		
310	35	290	10		
		290	25		
		290	26		
		294	1		
		294	2		
		294	5		
		294	17		
		294	21		
		294	25		
		294	29		
		294	43		
		294	50		
		294	64		
		294	67		
		294	74		
		294	77		
		296	2		
		296	6		
		296	9		
		296	17		
		296	21		
		296	35		
		296	41		
		296	50		
		319	2		
		319	11		
		319	21		
		319	23		
		319	34		
		319	75		
		319	76		
		326	6		
		326	8		
		326	17		
		326	33		
		326	34		
		326	45		
		326	57		
		326	62		
		329	1		
		329	20		
		329	21		
		329	39		
		329	44		
		343	4		
		343	6		
		343	18		
		343	29		

DC-8

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
		343	36		
		343	48		
		343	49	73	15
	22	343	50		
115	8	079	36	079	4
115	13			079	9
115	16	080	7	079	15
115	31	080	13	079	26
115	35	080	14	079	68
		080	20	079	69
126	11	080	22	079	70
127	4	080	34	079	74
127	6	080	40	079	86
127	49	085	2	079	87
127	50	085	16	079	90
127	52				
127	54	086	3	085	18
		086	5	085	19
136	2	086	14		
136	7	086	23	090	2
136	39			094	9
136	40	090	21	094	14
136	48	090	29	094	18
136	63	090	50	094	21
136	71			094	24
136	78	098	29	094	33
		098	36		
140	1	098	64	111	2
140	6	098	74	111	11
		099	1		
141	18	099	6		
148	25				
		118	3		
		126	8		
		126	12		
		126	14		
		127	19		
		136	16		
		136	24		
		136	31		
		136	51		
		140	15		
		140	16		
		140	17		
		141	3		
		141	8		
		141	14		
		141	15		
		147	6		
		147	9		
		147	10		
		147	11		
		147	18		
		147	23		
		147	30		
		148	8		
		148	11		
		148	13		
		148	25		
		148	36		
		148	44		
		148	50		
		148	56		
	24		54		22

DC-9

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
282	3	288	4	319	45
310	38	288	5	319	56
310	39	288	9	325	11
323	2	288	15	325	14
339	1	288	16	325	15
339	4	288	26	325	21
		288	27	325	30
		288	32	325	31
		288	37	325	41
		288	46	337	2
		288	50	337	7
		288	63	337	23
		288	80	337	26
		288	95	337	35
		290	1	337	36
		290	7		
		290	17		
		290	21		
		294	3		
		294	14		
		294	15		
		294	31		
		294	34		
		294	58		
		296	24		
		296	27		
		296	44		
		296	48		
		319	3		
		319	10		
		319	28		
		322	8		
		326	2		
		326	9		
		326	12		
		326	23		
		326	40		
		326	52		
		329	10		
		329	26		
		329	47		
		343	2		
		343	21		
		343	23		
	6		44		15
115	9	080	3	079	8
115	14	080	10	079	11
115	17	080	31	079	14
115	18	080	43	079	19
115	20	085	6	079	28
115	28	085	24	079	48
118	9	086	2	079	57
118	26	086	21	079	72
127	25	090	41	085	21
127	42	090	53	085	23
136	8	098	9	086	22
136	11	098	15	090	3
136	57	098	27	090	4
140	4	098	41	090	6
140	11	098	50	090	8
148	22	098	62	090	13
		099	9	094	12
		115	10	094	16
		115	11	094	35
		118	20		
		127	13		

DC-9

10 knots		10-20 knots		20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
		127	14		
		127	24		
		127	56		
		136	14		
		136	21		
		141	2		
		141	5		
		147	27		
		147	28		
		147	31		
		147	33		
		148	2		
		148	37		
	16		34		18

DC-10

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
		283	10	319	16
		288	59	319	55
		290	18	337	24
		294	29	337	43
		294	51		
		296	26		
		296	39		
		296	52		
		319	72		
		326	27		
		326	30		
		326	44		
		326	55		
		326	61		
		329	11		
		329	45		
		343	14		
		343	15		
		343	25		
			19		4

L-1011

< 10 knots		10-20 knots		> 20 knots	
Day	Run No.	Day	Run No.	Day	Run No.
310	1	288	54	319	18
		288	97	319	53
		290	29	337	9
		294	22	337	17
				337	40
		296	37		
		322	7		
		326	36		
		326	58		
		329	14		
		329	51		
	1		10		5
127	31	080	42	079	64
136	65	090	19		
		090	32		
		090	52		
		136	29		
		136	70		
		141	9		
		147	24		
		148	48		
	2		9		1

VC-10

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
290	31	293	6		
		288	91		
		294	72		
		326	29		
		329	12		
	1		5		

BAC-111

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
		343	5	325	34
		343	9		
			2		1

MISC

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
288	116	296	36		
310	7	329	6		
310	24				
	3		2		

VC-10

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
136	22	090	23	079	51
136	34	098	31		
		098	51		
		099	2		
		118	16		
		127	28		
	2		6		1

BAC-111

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
115	23	098	3	079	5
115	30	098	12		
		098	21		
136	1	098	26		
140	3	098	37		
		115	37		
		118	5		
		118	7		
		118	22		
		141	6		
	4		10		1

MISC

< 10 knots		10-20 knots		> 20 knots	
Date	Run No.	Date	Run No.	Date	Run No.
		098	54		
			1		